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THE METRIC SYSTEM.

II.

OBJECTIONS TO THE METRIC SYSTEM CONSIDERED.

In all that I have hitherto said, I have not dwelt one moment upon the intrinsic merits of the metric system itself. I have not thought that necessary. I am addressing intelligent men who know the system, and who know that, for the whole circle of our dealings with quantities, it stands, for easiness of apprehension, for convenience of use, and for the degree to which it facilitates reductions, precisely where our federal currency stands, among systems of money. The simplicity of the relations, moreover, by which it connects the measures of surface, of capacity, and of weight, with the linear base, is such as is nowhere else found; and such as to make of the system a powerful intellectual machine, and an educational instrumentality of inappreciable value. All this I pass by. But I cannot pass so lightly by the objections which have been urged against the system, and of which, in my view the importance has been, in most instances, exaggerated beyond all reason; since, through the wide circulation of the report of your committee on this subject, the high authority of this learned convocation has been made liable to be popularly regarded as attesting their gravity. Consistent with the duty imposed upon me on this occasion, therefore, I cannot pass them by; although the extent to which I have already trespassed upon your indulgence forbids that I should examine them with all the fulness that I could desire.

We are told, then, first, that the linear unit of the system is too large. Too large for what? Too large in the words of your Committee, "to be apprehended by a young and uninstructed mind." This is something which I confess that *I* do not apprehend. A metre, I suppose, can be brought into the school-room; and can be seen without difficulty, even by a very small boy, from end to end. I remember, when I was a very small boy myself, seeing something brought in which was about as long as a metre; and if I did not apprehend it at the time, I was at least very apprehensive of it.

But Mr. ADAMS says the metre is too long for a pocket rule. "Perhaps," he remarks, "for half the occasions which arise in the life of every individual for the use of a linear measure, the instrument to suit his purposes, must be portable, and fit to be carried in his pocket. Neither the metre, the half-metre, nor the decimetre is suited to that purpose." What then would Mr. ADAMS have? Would the foot rule fit into a man's pocket more conveniently than the decimetre? Does any man carry a foot rule in his pocket in any other than a folding form? And cannot a folded metre be carried in the pocket as easily as a folded foot? I at least find it so; as this rule proves, which I here present you. But since we have not yet adopted the metre as our unit, and since, after all, in

spite of what Mr. ADAMS says, or anybody else says, it happens to be notorious that a foot is *not* the measure which, "for half the occasions which arise in the life of every individual," is the most useful; the portable measure which we commonly find in men's pockets is a tape measure of a yard or a fathom in length, put up more compactly than is possible for any rule, whether long or short.

As to what *ought* to be the value of the standard length-unit opinions differ. The British standard is a yard. The Russian is the sagene, more than twice as long. Capt. PIAZZI SMYTH almost fanatically attaches himself to the inch, a measure which he believes with implicit faith to have been divinely given to CHEOPS, builder of the great pyramid, and again to MOSES in the wilderness; and in what he, no doubt, regards as the great work of his life, he uses no other to express the largest dimensions.

But it is also said that there are things to be measured in the common affairs of life that are less than a metre. I should suppose so. There are likewise many things to be measured less than a foot, or an inch. They measure these things in England even though the yard is their legal standard. In mechanical engineering, in France, the centimetre is the unit; in physics the millimetre. It does not unfit them for these uses, that their names happen at the same time to be expressive of relation to the standard. The metric unit of weight in commerce is the kilogramme; in analytic chemistry and pharmacy it is the gramme. The metric unit for dry measure is the hectolitre; for liquid measure, it is the litre; the metric agrarian unit is the hectare; the metric itinerary unit is the kilometre. It is in fact one of the merits of the system, that while, like all other systems, it allows any denomination to be made a unit measure for special purposes, yet it allows instantaneous transformations from one deuomination to another without changing a figure, but by the simple removal of a point. This cannot be done in non-decimal systems. The inch, for example, is with us the unit of the mechanical engineer and the draftsman. The rod is the farmer's unit of distance. But to reduce inches to feet you must divide by twelve, changing all your figures; and to reduce rods to feet you must multiply by sixteen and a half. This plan does not seem to me preferable to the metric. When your committee say that in their opinion "other units besides the base-unit should be used, as secondary bases for collections of numbers," I agree with them. It is what, in the employment of the metric system, I have always been in the habit of doing myself. But if, when they say this, they mean to say that values expressed in units of these secondary bases ought *not* to be transformable by the simplest processes possible into units of the standard base, my impression is that they will fail to carry the world along with them.

Another serious difficulty is started, of an educational character. Ten, it seems, is a difficult number to grasp, and one-tenth part is a still more difficult fraction. We can never know anything about one-tenth, "until we have divided the unit into two equal parts, into three, into four, and so on up to ten." Since this is the case, it is melancholy to reflect how much more objectionable is our actual system of weights and measures than the metric; since it will be necessary to divide the foot into two equal parts, into three, into four, and so on all the way up even to twelve, before the faintest conception of an inch can begin to dawn upon our minds; and when we turn our attention to the pound and the ounce avoirdupois, the formidably protracted extent of this unavoidable operation becomes quite disheartening. Still, however grave this business of ten may be, I suppose that our children must some time or other know something about decimal arithmetic; and they will have to know something about it whether they learn the metric system or not. If they know it, they know the system, all but its nomenclature; if they don't know it, then I can conceive no educational machinery better suited to make them know it than the visible magnitudes of the metric measures placed before their eyes. The question is not whether we shall teach the metric system to babes; but whether we shall teach it along with the arithmetic, and as a part of the arithmetic, which boys must learn at any rate. The objector does not apparently discover that his argument is no less damnatory to our Federal currency than to the metric system; yet my observation in the streets of New York satisfies me that gamins of very tender years, without having enjoyed the

advantage of scholastic culture or having been carefully and systematically carried through the mental operation of dividing the unit into two parts, into three parts, into four parts, and so on up to ten, acquire an acute appreciation of the relative value of a dime stamp and a nickel.

It is objected again that while the decimal ratio is infinitely more favorable to calculation than any other, yet for sensible objects, and for the daily purposes of life, the binary subdivision is to be preferred. If so, then let us use the binary so far as convenience may demand. There is no need on this account to reject the decimal, which for purposes of calculation is of priceless value. No harm is going to arise from employing both. We divide the dollar certainly into halves and quarters, to our great convenience; and the decimal system of the Federal currency is none the worse for that. We used to divide it into eighths and sixteenths even; and Mr. ADAMS says that, if the Spanish mint had not furnished us with coins representative of these values, we should have been obliged to coin them themselves. Yet within ten years after Mr. ADAMS wrote, we had effectually swept ou all this fry of foreign coinage, and nobody now perceives the want of it. Again, the Swiss pound is half a kilogramme. Take half any number of Swiss pounds and you have kilogrammes. Double the number of kilogrammes and you have Swiss pounds. The Swiss, moreover, use both the decimal and the binary subdivision. I presume they would not do this if they did not find it for some purposes useful, as we do in our Federal currency. The Swedes, some fifteen years ago, introduced the decimal subdivision, but they still retain some binary relations. Some such binary relations are recognized also by the French law; but it does not therefore follow, as your committee infer, that this fact "must give rise to much confusion." Neither is it true, as they also maintain, that we cannot adopt the essentials of this system without "adopting it as a whole and excluding every other:" by which I understand them to mean that we shall not even adopt metric values for our units, as Denmark has done, and as Austria has done, and as Turkey has done to a certain extent, without adopting the nomenclature throughout, and sternly prohibiting the use of all binary division; or that we shall not adopt if we please the decimal relations as Sweden has done, without adopting either metric values or the nomenclature; nor adopt the metric values and the decimal system complete, and yet reject the nomenclature, as Holland continued to do for half a century, and has only ceased to do within the last two years. Surely, things that other people have done, we may do; nor is there going to be, as your committee apprehend, any "fierce conflict" about the matter, nor any need to talk about "the spirit of a free people," or to insist on the fact that Americans are not habituated to "blind obedience to imperial edicts."

Can it not be understood that nobody of the great party who are seeking metrological reform and perfect international accord on this important subject, is bigotedly devoted to the metric system for its own sake; or resolutely determined to yield nothing that is in it, or to accept nothing that is not in it, on any consideration whatever? Their battle is for a *common* system, be that what it may; but if they believe that that common system will be found at last to embrace the main features of the metric system, they are not to be told that they shall have nothing else, if anything else superadded to it will make it either theoretically or practically any better. Mr. ADAMS wrote fifty years ago. What he wrote seems to have impressed your committee much more forcibly than all that has happened since. But the world has moved since the time of Mr. ADAMS, and it is perhaps not quite in order to tell us that if we think it a good thing to divide by ten, we shall never be permitted to divide by any other number so long we live. The first great point to be secured is commensurability of unit bases. That point once gained, the battle is substantially over. As for nomenclature and subdivisions, however important these matters may be, their importance is secondary, and they may be attended to afterwards.

Sweeping propositions are rarely wholly true. It is not a fact that binary subdivisions of weight and measure are always necessarily the best. In small dealings, the convenience of buyers and sellers is best consulted, when the multiples and submultiples of quantities correspond with

the multiples and submultiples of coins. If a pound of any commodity costs twenty-five cents, it would suit all parties who use the Federal currency better if we could divide the pound evenly into five parts, than it does now to divide it into four. Nothing is more certain than that quantities bought and sold, and the instrument of purchase and sale, should be subject to the same law.

But, as just remarked, the first point and the great point to be secured, is commensurability of unit bases. This can be accomplished if we please, with great facility. Our foot differs from three decimetres by a very inconsiderable fraction—less than two-tenths of an inch. If we make this slight change in the length of our foot, we are in harmony with nearly all of continental Europe. As for the other measures, they present no difficulty when the measure of length is once adjusted; for measures of length determine the dimensions of permanent constructions, while pounds and gallons are for ascertaining quantities of substances usually perishable. Men are disposed therefore to adhere with more obstinacy to their measures of length than to those either of weight or of volume. Mr. ADAMS's report shows that, in the past history of England, nothing has been more unstable than the value of the pound, the bushel and the gallon. There was a time when the gallon of liquid capacity contained only 216 cubic inches—in one sense a judiciously chosen value, since it was just one-eighth part of a cubic foot. The dry measure gallon contained, at the same time, 264.34 cu. in., corresponding to a bushel of 2,114.68 cu. in. And there was a ratio connecting the liquid and dry measures, which was that of the specific gravities of wheat and Gascon wine. Mr. ADAMS is quite enamored with this duplicity, which extended to the weights as well, between which the ratio has been pretty closely preserved down to our time. But this liquid gallon went on, as Mr. ADAMS explains, to be successively 217.6 cu. in., 219.43 cu. in., 224 cu. in., and finally as with us now 231 cu. in. As to the bushel, it seems to have had all sorts of value. By statute of 1496, passed in the reign of Henry the VII., it seems to have been ordered that this measure should contain 1792 cu. in.; but this statute was never carried out. There are two exchequer standards of this reign, one of 2124 cu. in., and one of 2146 cu. in., which latter is called the Winchester bushel. But then, under HENRY VIII., we have the large bushel of 2256 cu. in., from which came the ale gallon of 282 cu. in., so long in use with us. A bushel afterwards appeared of 2148.5 cu. in., and subsequently the Winchester bushel was found to have somehow worked its way up to 2150.42 cu. in.; at which value it was in 1701 made the standard in England, and so became the standard with us, as it continues to be yet. But just four years after Mr. ADAMS so strongly expressed his regrets at the destruction of the "uniformity of proportion" contemplated by the beautiful theory of the British measures, the British Parliament took this whole business in hand. Instead of improving the capital opportunity afforded them of correcting the irregularities which his report signalizes, they quietly struck out of existence every measure of capacity in use, whether wet or dry; and established the system of imperial measures, wherein the bushel contains 2218.1907 cu. in., and the gallon 277.-2738 cu. in., to be used equally for commodities of all descriptions. This was a tolerably formidable change and a tolerably sudden change; but it occasioned no insurrection; nor did the people even run after the carriages of the ministers, shouting "give us back our bushel;" as we are told they shouted in 1752, "give us back our eleven days," when the Gregorian was first introduced into England. Changes of metrological systems, then, are possible, and are possible even for us, without provoking "fierce conflicts." All that is necessary is that the people should know what they are, and should feel that they are desirable.

Your committee themselves are not averse to all change. There is one modification of our system of weights which they actually propose to our acceptance. The recommendation is made moreover so impressively, out of sense of "duty plain and imperative," that for one I was prepared for something startling; for at the very least a proposition to do away forever with the perfectly unnecessary Troy pound. I am compelled to confess my disappointment. The proposed innovation so solemnly introduced is explained in the following words: "In analyzing these weights, it is found that the ounce

in the apothecaries' weight and the ounce in the weight Troy are identical, and that each exceeds the ounce avoirdupois by its eighty-three-thousandth part very nearly; hence, if the ounce Troy, or the apothecaries' ounce, be diminished by its eighty-three-thousandth part, the result will be the ounce avoirdupois, or the one thousandth part of the weight of a cubic foot of distilled water, and then these three weights will have a common unit."

I have pondered this passage profoundly, but I have not been able to see my way to the bottom of it. It has been my lot to be compelled to transform Troy ounces into avoirdupois ounces very frequently; but I have always found the difference to be 42.5 grains, while it is here apparently hardly six one-thousandths of one grain. Presuming, however, that something may have been intended which is not said, and that, at any rate, it is designed somehow to make the Troy and apothecaries' ounce equal to the avoirdupois ounce, I accept this proposition as a concession so far as it goes to the cause of uniformity and simplicity; but I ask what justification can exist after abolishing the smaller denominations, which alone are used by the jewellers and dealers in bullion, or even by the druggists (for the wholesale drug trade is carried on in avoirdupois pounds)—what justification can exist after this, for retaining the pound of twelve ounces.

I would point out further that, since the ounce, after being reduced by nearly its eleventh part, is still, according to the proposition of your committee, to consist of four hundred and eighty grains, the grain must accordingly be reduced in the same proportion; so that all the confusion which could arise in pharmacy and the trade in precious metals from changing the grain for the milligramme, whereby something might be gained, will be here introduced without gaining anything at all.

It has been furthermore urged as a fact very injurious to the pretensions of the metric system, that this system has never been permanently applied to the division of the circle, to which, if to anything, it ought to be peculiarly adapted. Those who use this argument ought to remember that the Arabic numerals, the symbols of algebra, and the division of the circle, are three things, (and the only three things, I believe,) which were the same for all civilized mankind, when the metric system was created. To change the law of circular division was to introduce diversity where uniformity prevailed before; and also to destroy the usefulness of a vast scientific literature which had been founded on the sexagesimal division. Yet the French did make the experiment of dividing the quadrant centesimally, both in tables and in instruments; and what was thought of its convenience by the ablest astronomers and geodesists of that day may be inferred from the following incidental remarks of DELAMBRE, in his description of the operation of measuring the great French meridian arc. "Three of our four circles," he observes, "were divided into decimal grades or degrees, each having the value of $360° \div 400 = 0°.9 = 540' = 3240''$. This division is much the most convenient for the uses of the repeating circle, and would be equally so for the verniers of all instruments whatever. Many persons hold to the old system by habit, and because they have made no use of the new; but no one of those who have practised both will willingly return to the old."

When the metric system shall be universal, it is probable that the decimal division will be once more applied to the circle. Nothing could be less convenient than the sexagesimal which is now employed. And in point of fact, this law of subdivision has been already abandoned for all values below seconds; such values being now invariably expressed decimally, though, two or three hundred years ago, it was carried to thirds, fourths, and even fifths, as may be seen in any old astronomical work, or in DELAMBRE'S *History of the Astronomy of the Middle Ages*. I regard this objection therefore as without foundation.

But it is apparently a very strong point with most objectors to the metric system, that our present measures of length have their representatives—the assumption is that they have their prototypes—in the dimensions of some parts of the human body. Thus, your committee say, the foot "was undoubtedly adopted as a standard of measure from the part of the body from which it takes its name." Some foot was undoubtedly so adopted, but what foot? The Greeks used the foot earliest, and the Olympic foot is said to have been the measure of the foot of HERCULES. But there were foot measures in use among

them of several other magnitudes; and while it is difficult to know with certainty what any of them were, compared with ours, it is not difficult at all to ascertain that they differed widely among themselves. Thus the authorities state that the Macedonian foot was 14.08 in., the Olympian 12.14 in., the Pythian 9.72 in., and the Sicilian 8.75 in. Here, in the earliest history of this measure, we have the largest room for choice. In more recent times, the diversity has been greater still. Thus in Italy the foot was, not long ago, 11.62 in., in Rome; 13.68 in. in Lombardy; 23.22 in. in Lucca. In France it was 9.76 in. in Avignon; 9.79 in. in Aix-en-Provence; 10.57 in. in Rouen; 14.05 in. in Bordeaux; while the *Pied du roi*, for France generally, was 12.79 in. In Switzerland, it was 10.52 in. in Neufchatel; 11.33 in. in Rostock; 11.99 in. in Basel, and 19.21 in. in Geneva. In the Spanish Peninsula it was 10.12 in. in Aragon and 10.96 in. in Castile. In Germany it was 9.25 in. in Wesel; 10.89 in. in Bavaria; 10.998 in. in Heidelberg; 11.45 in. in Gottingen; and 13.12 in. in Carlsruhe. In the Netherlands it was 10.86 in. in Brussels, and 11.28 in. in Liege. These examples will suffice, but there are plenty more behind.

It can hardly be supposed that all these measures were taken from the human foot; it is hardly probable that any of those used in the later centuries were so. The name has been perpetuated from a very early time; but the thing named has either lost by degrees its original value, or it has been arbitrarily changed. As to the origin of the British foot, it is pretty easily explained. There is no reason to doubt the account commonly given of the adjustment of the yard from the arm of Henry I., in 1101. The foot is certainly derived from the yard, which has always been the standard of length in England, and is simply the third part of that measure. I know that we are continually told that our American foot is in length but a fraction in excess of the average foot of man. It astonishes me that any one who has two feet to walk on himself should ever entertain this opinion. The length of the human foot is given in the *Encyclopedia Britannica*, (authority Dr. THOMAS YOUNG) as 9.768 inches. Upon how large an extent of observation this determination is founded, is not known; but the question in issue is pretty well settled in the volume of "*Investigations in the Military and Anthropological Statistics of American Soldiers*, by Dr. B. A. GOULD," published among the Memoirs of the U. S. Sanitary Commission in 1869. Nearly 16,000 individual men, volunteers for the army, of very various races and nationalities, were subjected to measurement, of whom about 11,000 were white and the rest colored. Dr. GOULD says: "The mean length [of the foot] was found for no nationality to exceed 10.24 inches; and for none to fall below 9.89 inches; the value for the total being 10.058 inches," or about a twentieth of an inch above ten inches. This approaches much more nearly to a quarter of a metre than to a third of a yard. Let it be understood that nobody is objecting to the foot measure. It is a very convenient measure to have. If it were slightly modified so as to be equal to three decimetres, it would be more desirable still; but it is quite unnecessary to defend it on the ground that it is the measure of the human foot; and it is judicious not to do so, because that happens not to be the case.

However, the facility of measuring off the yard on the arm is a fact which furnishes to the objector firmer ground. We *can* do that. Sir JOHN HERSCHEL'S rule is, "Hold the end of a string or ribbon between the finger and thumb of one hand at the full length of the arm extended horizontally sideways, and mark the point that can be brought to touch the centre of the lips, facing full in front." Very well; now if you will carry the string or ribbon entirely across the lips and mark the point that can be brought to touch the angle of the jaw or the lobe of the ear, you will have a metre. Or, if you carry the ribbon across the breast instead of the lips, and bring it to the point characteristic of that part of the person, you will have a metre once more.

The breadth of the palm is a decimetre; the breadth of the little finger at its extremity is a centimetre. A pace is an artificial step, and not a natural one; but suppose that it were natural for us to stride three feet, or, suppose, at any rate, that we have learned to do so; and suppose that a metre is too large a step to be easily acquired; a pace is practically nine-tenths of a metre, and any number of paces are reduced to metres by dropping a

tenth part. Thus, fifty paces are forty-five metres, and one hundred paces are ninety metres. This reduction is the simplest of all possible processes. Thus, I do not see that, by adopting metrical measures, we are going to be in the slightest degree disabled from finding, in the dimensions of our own persons or of our steps, all the means of effecting rough measurements which we possess at present; and this objection falls to the ground.

But there is still another practical objection which is so perfectly well founded that I hardly know what to say about it; so that I am not sure that the truest wisdom in me would not be to let it alone altogether. It is the undeniable truth that, *if we give up our present measures we shall cease to have them any longer.* "What follows?" say your committee with anxiety: "we have blotted from the mind of the nation the foot and a knowledge of every measure into which it enters as a unit." This is evidently a serious business. It reminds us of the sad case of the lad, who, having eaten his cake, desired to have it again. The committee go on to explain that, instead of twenty-five feet we shall have to say something else; and instead of one hundred and forty-five miles we shall have to say something else still. And exploring the extent of the calamity, the committee become gloomily figurative; and speaking with deep emotion of "the cubic foot, known wherever the English language is spoken," they tell us that this cherished object "is also gone, and in the twilight of its existence, we grope about for a substitute." I do not deny that this is eloquence; but I respectfully submit that it is not argument. There cannot but be some of us who will consider that this tenderly lamented cubic foot, with its inconvenient numerical relation to the cubic inch of 1728 to 1; and its more inconvenient relation to the common unit of liquid capacity of 1728 to 231; and its even still more inconvenient relation to the unit of dry capacity of 1728 to 2,150.42, is very well out of the way.

I will not attempt to follow the committee further in their lament. But I cannot omit to notice, in passing, the perplexing embarrassment of the honest man who, setting out to purchase the convenient quantity of fourteen pounds of beef for his dinner, after there have ceased to be any pounds, is astounded at finding that he will be compelled to pay for the amazing number of grammes expressed by the figures six thousand three hundred and fifty-six: or in case that he is bankrupted by this huge demand, will be permitted to compromise the matter only on condition of buying six kilogrammes, three hectogrammes, five decagrammes, and six grammes. I wish to present a parallel to this. I go to my tailor for a coat, and he states to me the price, in a sum expressed by the four digits named above, in the same order, viz,, 6, 3, 5, 6. The committee has given the general rule for reading concrete decimal numbers, as follows: "All the readings are made in the lowest unit." Hence, the cent being the lowest money unit involved in the price named, my tailor is under the necessity of informing me that I can have the coat for six thousand three hundred and fifty-six cents; and it will not be lawful for him to vary the form of expression in any manner unless to say, by way of alternative, that he will give me the coat for six eagles, three dollars, five dimes and six cents.

I would, however, advise the unfortunate man who finds so much trouble with his marketing, not to buy his meat by the pound after pounds have gone out of date; but to content himself with a round six kilogrammes, or, in case he is very hungry, say six and a half.

As it respects the objection that the introduction of the new measures would invalidate the titles to lands held under old surveys, nothing can be more imaginary. No legislation on this subject can be retroactive—it would not be constitutional if it were. The registry of deeds in the past would continue to have the same validity as now. In making a new deed in the future nothing would be easier than to translate the language descriptive of linear and superficial dimensions from one form of expression to the other. Changes should thus come on gradually, as property should change hands. Deeds have to be made anew when sales are effected, and only then. The labor of making them in one form or the other is precisely the same.

One final objection, or pair of objections allied to each other and closely connected together, I have reserved to be considered last. Some gentlemen honorably eminent in science have criticised the metric system on the ground that its base is not well

chosen. This base purports to be the ten-millionth part of a quadrant of the terrestrial spheroid. But it is said the earth is not a spheroid, being rather an ellipsoid of three unequal axes; whence it follows that the meridians are unequal, and that the metre, if truly the ten-millionth part of one quadrant, is not a ten-millionth of any other differently situated in the ellipsoidal surface. The polar axis of the earth, on the other hand, is the common minor axis of all meridians; it is a magnitude entirely unique; and, even if the earth were a true spheroid, there would be a higher degree of scientific fitness, there would be something on which the mind would dwell with more entire satisfaction, if we should take a fraction of that axis as the base of a system of metrology, than a fraction of any quadrant, or any other known magnitude. This is the view of Sir JOHN HERSCHEL and of Capt. PIAZZI SMYTH, and if the whole thing were to be done over again, it would probably be the unanimous view of the scientific world. But the matter has gone too far now to change the base. In the meantime, therefore, there is no impropriety in saying, that it is by no means yet proved that the earth is an ellipsoid. Neither, indeed, is it proved that it is a spheroid, if by that word is to be understood a figure geometrically true. What *has* been proved may be understood from the following succinct statement.

There have been measured upon the surface of the earth, in all, excluding remeasurements, some sixteen meridian arcs. Most of these are very short, not exceeding three or four degrees in length, and generally less than two. The longest of them all is the Russian arc, of twenty-five and one-third degrees; and the shortest, the first Swedish arc, measured in 1737, by MAUPERTUIS, of fifty-seven and a half minutes. Two short arcs have been measured on the American Continent, one in Peru and one in Pennsylvania. The latter, only about one a half degrees in length, was measured by Messrs. MASON and DIXON in 1767, without triangulation, and is esteemed of comparatively little value. The Peruvian arc, which is rather more than three degrees long, was admirably triangulated by BOUGUET and LA CONDAMINE, in 1735, and the two or three years succeeding. A short arc of about a degree and a half was measured at the Cape of Good Hope by LACAILLE in 1751. In this measurement, the effect of local attractions on the plumb-line was such as to lead to very erroneous conclusions. This arc has been recently re-examined and extended to more than four and a half degrees, by Messrs. HENDERSON and MACLEAR; this operation bringing to light the causes which had vitiated the former. A long arc of twenty-one and a third degrees has been measured in India. With the exception of the Indian, the African, the Peruvian, and the Pennsylvanian arcs (the last hardly meriting to be included in the enumeration), all the rest are in Europe, and are embraced within limits of longitude differing, at widest, but about twenty-seven degrees.

Now supposing the earth to be a spheroid, it matters not, for the determination of its figure, what are the longitudes in which meridian measurements are made, provided the latitudes are different; for on this supposition degrees in the same latitude are equal everywhere. Also, if the spheroid is oblate, the curvature in the higher latitudes will be less and the degrees longer than in the lower. Now, as in an ellipse the linear amplitudes of any two arcs differently distant from the apsides, along with the angles made by the normals at their extremities, suffice to determine the axis and the eccentricity, it was to be expected that a comparison of any two properly selected meridian arcs measured upon the earth's surface in different latitudes, would furnish constantly the same value of the polar and equatorial diameters, and the same value for the compression of the poles. But this expectation has been singularly disappointed. The international scientific commission which, in 1799, fixed definitely the length of the metre, in comparing the French arc with the Peruvian arc, made the compression of the earth one 334th: but Messrs. LAPLACE and LEGENDRE, both eminent geometers, members of that commission, by comparing one portion of the French arc with another, made it, the first 1-150th and the second 1-148th. DELAMBRE, one of the geodesists who effected the measurement, deduced from his comparisons with the Peruvian arc, the value, one 312th, and afterwards one 309th. The French arc was subsequently extended southward nearly three degrees more; making a total length of twelve and one third degrees, when a recomparison

with the Peruvian arc by DELAMBRE gave a compression of one 178th. The effect of these differences of result upon the calculated length of the quadrant of the meridian passing through Paris would not be very great, upon the hypothesis that the earth is really a spheroid ; for it happens that the French arc is so situated as to give very nearly the value of the mean degree, independently of the eccentricity. But if the earth is an ellipsoid, it is evident that it is entirely wrong in principle to compare two arcs with each other, when they differ materially in longitude.

Now it is a part of the history of this subject that, in the year 1859, Gen. T. F. DE SCHUBERT, an officer of the Russian army of distinguished ability, after a laborious series of comparisons of several arcs combined two by two in all possible ways (the arcs were eight in number, and the combinations twenty-eight), found such remarkable discordances, that he felt himself forced to the conclusion that the earth is not spheroidal, but must be ellipsoidal in form. The compressions found by him varied, for instance, between the wide extremes of one 14501st, and one 116th; and the difference between the largest and smallest value for the polar axis amounted to 362,126 feet, or 68.584 miles.

Now observe what these deductions prove, and what they do not prove. They prove certainly that the earth is not a perfectly regular spheroid, and in this they are corroborated by other evidences; but they do not prove it to be an ellipsoid. The corroborating evidences just alluded to may be slightly glanced at in passing. In the first place, the successive degrees of the French arc do not increase, in going northward, in the manner they ought if the meridian is truly elliptical. And, secondly, it is true, that after that arc had been extended southward, as above-mentioned, to the Island of Formentera, in the Mediterranean, the degrees at the southern extremity were found actually to diminish in going northward, instead of increasing, as in a regular ellipse they should have done.

Colonel EVEREST also, the accomplished geodesist, who executed the measurement of the northern section of the great Indian arc, found that, when he compared the northern half of the northern section with the southern half of the same section, he obtained an eccentricity of one 192d; but that when he compared the southern half with of the northern section with the whole southern section, the resulting ellipticity was only one 390th, or one-half as great. The values of the polar axis of the earth also, obtained from these comparisons, differed by 67,106 feet, or about 12.71 miles.

These facts (and many like them might be stated) are to be borne in mind in judging how far the method of General DE SCHUBERT, with the data thus far gathered to go upon, is to be trusted This gentleman, concluding very properly that comparisons of arcs measured in different longitudes are unworthy of confidence, resolved to deduce values of the polar and equatorial diameters of each meridian, by such comparisons as that of Colonel EVEREST just described. But here his material is at once largely reduced; for of the eight arcs employed in his previous comparisons, only three are long enough to permit the application of this method, viz.: the Russian, twenty-five and one-third degrees; the Indian, twenty-one and one-third degrees, and the French, twelve and one-third degrees. The British arc is now long enough to allow a fourth comparison (ten and a quarter degrees), but it is so nearly in the meridian of the French arc that it may better be treated as a prolongation of that. Gen. DE SCHUBERT divided each of his three arcs into two parts each, as nearly equal as convenience would allow. From each he deduced a value for the major and minor axis of the meridional ellipse. If his hypothesis was true, the minor axes should have come out equal and the major axes unequal. The latter anticipation was realized, but the former only imperfectly so. The polar axis found from the Russian arc, compares pretty well with that found from the Indian; differing only about fifteen hundred feet, or rather more than a quarter of a mile; but the difference between the values of the same axis, as deduced from the Russian and the French, is fifteen thousand one hundred and sixteen feet, or nearly three miles. On account of this discrepancy Gen. DE SCHUBERT discards the French arc in this computation, and determines a value for the polar axis on the basis of the Russian and the Indian alone ; giving, at the same time, quite arbitrarily, twice the weight to the former as to the latter. And with

the axis thus determined and the aid of the Peruvian arc, he finds a third equatorial radius; which, combined with the Indian and Russian equatorial radii, enable him to place the axis of his imaginary equatorial ellipse. Finally, with the axes of the equator and their longitude, and also the equatorial eccentricity, he is able to compute the length of the equatorial radius corresponding to the French arc; and from that, the length of the theoretic French quadrant. Then, comparing this theoretic quadrant with the length of the same as deduced from the actual measurement of its ninth part, he feels himself justified in pronouncing the metre to be too short by the two hundredth part of an inch. I think it does not require a profound mathematician to see that the data on which this conclusion rests are too meagre to justify so important a deduction. The case is one to which Prof. HUXLEY's witty remark upon the power of the mathematics may be properly applied. "The mathematics," observes the Professor, "may be compared to a mill of exquisite workmanship, which grinds you stuff of any degree of fineness; but, nevertheless, what you get out depends on what you put in." And here it appears to me that we are not yet prepared to put in material enough to furnish us with a grist worth carrying away.

Prof. AIRY perceived the weakness of this method and pointed it out. He suggested an improvement on it which is worth more, and his suggestion was taken up by Captain A. R. CLARKE, an accomplished officer connected with the ordance survey of Great Britain. This method consists in bringing together the latitudes, determined both geodetically and astronomically, of as many stations as possible, upon selected meridian arcs; and then, all the elements of the problem being left indefinite, proceeding to ascertain what values given to the indeterminates will make the sum of the squares of the errors of latitude a minimum. He first presented his results to the Royal Astronomical Society, in 1860; and afterwards, having slightly modified some of his data, republished them in an appendix to a large volume issued in 1866 by the Royal Ordnance Survey. His last conclusion puts the metre in error one 172d of an inch. The number of latitudes employed by Capt. CLARKE in this investigation is forty. Some slight variations made upon a portion of those in the Russian and the French arcs, between the first and the second determinations, amounting generally only to very small fractions of seconds, produced a sensible difference in the length of the polar axis, in the value of the compression, and in the computed error of the metre; reducing this last from one 163d of an inch, which was his original determination, to one 172d, as given above. But Capt. CLARKE himself regards the data as entirely insufficient to make a correct determination of the earth's figure a possibility. His own words are: "It would scarcely, I conceive, be correct to say that we had proved the earth not to be a solid of revolution. To prove this would require data which we are not in possession of at present, which must include several arcs of longitude. In the mean time it is interesting to ascertain what ellipsoid does actually best represent the existing measurements." And having found this, he proceeds next to apply the same method, *i. e.*, the method of least squares, to the object of ascertaining secondly, what *spheroid* will best represent existing measurements; and he is brought thus to the conclusion that such a spheroid is nearly as probable as an ellipsoid; the numbers representing these probabilities being 154 and 138 respectively (where the smaller number indicates the greater probability). We may admit then that the ellipsoidal theory is slightly the more probable; and with this preliminary we are prepared to consider the two objections spoken of above.

The first is, that the earth's meridians being unequal, the ten-millionth part of a quadrant, even if we had such a measure correctly, could be only the ten-millionth of one particular quadrant, so that the ideal of a natural standard everywhere present and belonging equally to all the world must be abandoned. Still it cannot be denied that the quadrant chosen, though a particular quadrant, possesses the essential property of a standard, that is to say, invariability, quite as completely as if all the quadrants were equal. If this natural standard were intended to be, or were capable of being made, a standard of convenient reference, and not merely a standard of value, if, in other words, a tradesman, suspecting his metre to be in error, could adjust it by simply stepping out of his door and applying it to

the earth's meridian, there might be some reason for complaint on the part of those, and they would be the majority of mankind, whose distance from the standard would deprive them of this facility. This not being the case, no practical disadvantage arises out of the inequality of the meridians, and it is only the simplicity of the original conception that suffers.

The second objection to the base of the system—an objection which is often urged in a tone which implies that the objector regards it as nothing less than fatal—is that the metre is not, after all, exactly the ten-millionth part of the particular meridian from which it was derived. It is possible that it is not: nay, we may safely assert that it would be nothing short of a miracle if it were. We have glanced at the condition of the problem of the earth's figure and magnitude in the hands of the geodesists. We have seen that every meridian measurement which has yet been made has served but to accumulate evidence that this figure is not geometrically regular, and is not probably, if words are to be applied with severe exactness, either a spheroid or an ellipsoid. It will easily be understood that a local irregularity actually affecting but a limited extent of a terrestrial arc, may, when it is allowed to give character to a whole circumference, lead to extraordinary conclusions; and we have seen the fact that it will do so, illustrated in the examples cited from Col. EVEREST and others. What hope can there be that the effects of such irregularities can be eliminated by an investigation which, however admirable in principle and however ably wrought out, rests on a comparison of only forty latitudes? Not a single geodetic measurement has yet been made in all the immense expanse of northern and eastern Asia, of northern and central Africa, or of Australia and the Australasian archipelago. Nor, except in the small Peruvian arc, and the still smaller Pennsylvanian, which latter does not count, has the great American continent made any contribution to the solution of the difficult problem under consideration. When we consider, therefore, that the introduction of minute corrections, amounting only to small fractions of seconds, into only a part of the data employed in Captain CLARKE'S equations, suffices to modify the resulting dimensions of the earth to such an extent as to produce, as we have seen, a very sensible change in the calculated value of the error of the metre, I think that the assertion just now made will be admitted to be perfectly well founded, *i.e.* that if the length given originally to the metre had been exactly the ten-millionth part of the Paris meridian, this result would have been neither more nor less than a miracle. I may further add that, even if the metre had been quite correct, its authors could not have known it to be so, and we should not know it to be so now. When measurements shall have been made in those vast regions just mentioned, which have not yet been attacked by the geodesists, and when, instead of forty latitudes, four thousand shall have been thrown into the hopper of Prof. HUXLEY'S mill (though I confess that in such a case I should not be envious of the miller's task), we shall get out an inevitably different and a very certainly more satisfactory grist than has yet been ground for us. In the mean time we may as well take the metre as we find it, and not concern ourselves about this Protean and microscopic fraction of error, which has so long been thrown up to it as a reproach.

It is a little remarkable that the objectors who find the error of the metre to be so grave a blot upon its character, should nevertheless agree in urging us to accept a standard derived from another natural dimension of the earth, equally invariable no doubt with the quadrant, but at the same time equally unmeasurable—the polar axis or the polar radius. This is a dimension of which the authorities give us as many different values as they give of the quadrant; and of which they are sure to give us a new one every time an addition is made, no matter how trivial, to the data from which it is deduced. The values fluctuate perhaps between narrower limits of variation; and if the ten-millionth part of the earth's polar axis or the earth's polar radius were our theoretic metre, the absolute error of our practical metre would be probably rather less in proportion to its length, than that of the metre now in use. But the error would be there none the less; for, as before, it would be nothing short of a miracle if it were not; and between two errors, both of them microscopic, and neither of them affecting any conceivable human interest,

I see for my own part little to choose. If the advocates of the radius metre could come to the defenders of the quadrant metre, and say to them, "Here, you see, our metre has no error at all, and yours has one," the case would be a strong one; but that does not seem to be the case. Since these things are so, why then, you may inquire, should we endeavor to fix our standard of length with reference to either axis or quadrant or any other dimension which we do not know, and which it is perfectly certain that we shall never be able exactly to ascertain? That, gentlemen, is a question which you may very well ask, but which I shall not attempt to answer. I accept the metre as it is, not because it is the ten-millionth of the French quadrant (though, according to Capt. CLARKE, it *is* the ten-millionth part of the quadrant passing through New York, within less than the ten-thousandth part of an inch), but because it is the actual base of an admirable system of weights and measures already in use among one hundred and sixty millions of people, rapidly growing in favor among those who have not yet adopted it, and destined in my belief to be sooner or later the system of all the world.

But, gentlemen, I do not expect that this system will make its way in the world against the will of the people of the world. I do not expect that our people, and I do not desire that any people, shall be coerced into receiving it by the force of "imperial edicts" or the terror of bayonets. What I do expect is, that they will sooner or later welcome it as one of the greatest of social blessings. What I do expect is, that they will one day become conscious of the many inconveniences to which they are subjected from the anomalous numerical relations which connect, or rather we might say, disjoin, the several parts of their present absurd system; inconveniences which they have learned to endure without reflecting on their causes or suspecting that they were unnecessary in the nature of things: and that when fully at length awake to the slavery in which they live, they will burst its shackles, and rejoice in the deliverance which the metric system brings. This cannot take place, of course, until the people are thoroughly informed. There are influences, therefore, which are now only beginning to operate, which must first have their full course before the results I anticipate will make themselves manifest. The first and most important of these is the education of the young to a thorough understanding of this system, and a perfect familiarity with its practical applications. The metric system must be taught in all our schools. It ought of course be taught there, as being the system actually in use among nearly or quite half the inhabitants of the civilized world already, and without any regard to the question whether it is to be ours or not. But it ought to be taught, too, with special reference to this question; in order that another generation may meet it and settle it intelligently. And I think I hazard nothing in saying that when one generation shall have grown up into whose minds this knowledge shall have entered along with the first rudiments of their learning, the question will no longer have two sides.

But, in the second place, the system should be practically illustrated before the eyes of our people, by being introduced into our custom-houses, and made the guide according to which duties are assessed and collected. This measure will disturb the habits of no one in the affairs of ordinary life. Importing and exporting merchants will interpose no objection to the change. On the contrary, they will welcome it as greatly diminishing the amount of computation which they are now compelled to make. It is, in fact, the complaint of Capt. PIAZZI SMYTH, that it was the pressure of the commercial class which came so near to making the metric system the exclusive system in England in 1868. Our tariff laws will require transformation; but that transformation may be made without in any manner disturbing their essential provisions: so that no trouble need arise from this cause. What it is here proposed to do is nothing more nor less than what was actually done, some thirty years ago, by all the members of the German Zoll-verein. And though the state of things produced by it there will be superseded on the first of January, next, by the extension of the metric system in full over all the component states of the late North German confederation, if not over the entire German empire; yet it will still exist in Austria, and will continue to ex-

ist in that empire until she, too, shall adopt the same system for her domestic affairs likewise.

By degrees our Federal government may introduce the metric weights and measures into our public surveys; such as the coast survey, the several boundary surveys, the geological, topographical, and land surveys of the territories, and the surveys of the lakes. In the published reports of these works, or at least in such of them as are intended for, or are likely to have, a large circulation among the people, it would be advantageous, and would familiarize metric values to the popular apprehension, if dimensions, quantities, and weights should be expressed both in metric denominations and those of the existing system.

The metric weights and measures may further be introduced into actual use in the navy yards and military posts maintained by the government in the different parts of our territory: and, finally, the business of the post office department may be largely, if not wholly, conducted, so far as weights and measures are concerned, in metric denominations.

These are measures which were unanimously recommended by the international conference on weights, measures, and moneys, which was convened in Paris, in 1867, consisting of delegates appointed by the governments of twenty-two different nations, including, of those not using the metric system, Austria, Russia, Sweden, Norway, Denmark, Turkey, Great Britain, and the United States. To most of them, as it appears to me, there can be no reasonable objection, even on the part of those who have no admiration for the metric system themselves, and no faith in the prediction of its final prevalence. If nothing follows them, they can at least do no harm.

I have occupied, gentlemen, a larger portion of your time than I intended, and larger, I fear, than will have seemed to you reasonable. The subject itself is a large one, and my interest in it is deep. I am so far from pretending to have exhausted it, that I feel that what I have said is but the merest skeleton of an argument. I wish to be indulged only in a single additional remark, which shall be in regard to the able and comprehensive, and, at times, eloquent report of Mr. JOHN QUINCY ADAMS, which you have republished in the volume along with the report of your committee.

The original publication of that report, able and powerful as it is, and for the very reason that it is able and powerful, I esteem to have been a serious public misfortune. It effectually extinguished all hope of metrological reform in the United States for half a century. And yet Mr. ADAMS, decidedly as he discouraged any legislation, at least for the time being, and apparently for a very long time, looking toward the recognition of the metre in America; darkly as he drew in the lines as he painted the picture of France writhing in the toils which the metric system had thrown round her; and fondly as he lingered over that beautiful system of British weights and measures distinguished by the priceless property of a "uniformity of proportion" of which he laments that there remain to us only the ruins; Mr. ADAMS, after all, was an admirer of the metric system to such an extent, that one is sometimes at a loss to decide whether he seems to love or to fear it most. In the midst of his doubts and his misgivings, he cannot refrain from occasionally enlarging upon its merits, in language strong enough to satisfy even the most enthusiastic of its advocates. And when for a moment he succeeds in forgetting France, and in shaking himself free from the embarrassing associations of the immediate present, he becomes as it were inspired with a spirit of prophecy, under the influence of which he becomes oblivious of difficulties, and glowingly anticipates that very approaching triumph which his own labors are destined so considerably to postpone. No words that I can use can add to the positiveness of assertion with which he predicts that final consummation to which I have declared to you to-day that I so confidently look forward. I cannot do better, therefore, in concluding these remarks, to which I thank you for having so indulgently listened, than to adopt his own language, and to express with him the conviction that, "If man upon earth be an improvable being, if that universal peace which was the object of a Saviour's mission, which is the desire of the philosopher, the longing of the philanthropist, the trembling hope of the Christian, is a blessing to which the futurity of mortal man has a claim of more than mortal promise; if the Spirit

of Evil is, before the final consummation of things, to be cast down from his dominion over men, and bound in the chains of a thousand years, the foretaste here of man's eternal felicity; then this system of common instruments to accomplish all the changes of social and friendly commerce will furnish the links of sympathy between the inhabitants of the most distant regions; *the metre will surround the world in use as well as in multiplied extension;* and one language of weights and measures will be spoken from the equator to the poles."

A TUNNEL CHANNEL.

From "The Building News."

The triumph of the Mount Cenis engineers has revived a project which has long been in existence. It is nothing less than the tunnelling of the British Channel; and there are not wanting practical persons who, while appreciating the difficulties of the work, believe them to be by no means insuperable. We hear so much of the tedium, delay, and annoyances accompanying the present system of transit between France and England, that, no doubt, such a scheme, if shown to rest upon any probabilities of success, would be undoubtedly and universally welcome, though the tourists of the actual day could scarcely hope to derive much personal benefit from its execution. No doubt the generation which has created the Suez Canal and perforated the Alps has reason to put faith in its power of accomplishing other similar achievements, upon an even grander scale; but there is a vast difference between scooping an open channel through a desert, or hollowing a road with a mountain as its roof, and constructing a safe and solid highway with a peculiarly restless sea pressing upon its arch, and forever chafing against the superincumbent mass. It is true, beyond question, that an immense progress has been made since the Thames Tunnel was regarded as a miracle of engineering and a wonder of the world; yet a Channel tunnel would be an almost wholly dissimilar undertaking. Still there are men with sagacious heads, not likely to dream, who think the performance quite possible, and who would be willing to enter upon it, provided the one great necessity—an adequate capital—were furnished. One proposal is to avoid the chalk altogether, and following the Wealden, which contains prodigious masses of clay, extending from Dungeness to Cape Griznez, to burrow at a depth of 100 ft. below the bed of the sea, which, it is affirmed, could then be as easily kept out of it as the London pavements out of the London sewers. There is a rival line—on paper—from Dover to Calais; but we need not compare the two plans in detail. Both would run at an equal depth; the difference in point of distance would be only 1½ mile, and as a means of communication, the one would probably possess a little or no superiority over the other. The question, apart from absolute technicalities, is, are we likely to see this mighty enterprise taken in hand and completed? Now, as to its being an impossibility, that idea may be dismissed; but would it be worth the while of governments and speculators to assume the gigantic task, with all its many and undeniable chances of repeated disappointments and failures, and disasters to human life, of millions sterling swallowed up, of the labor being suspended, of one new capital after another being required, of contractors ruined and shareholders with them, and the sea being paved with more gold than the submarine traffic would ever repay? The engineers who have carried one railway through and another over the Alps, would indubitably not shrink from their own professional share in the resposibility; but there is much more than this to be thought of. They have brought us within a few weeks' journey of India, China, and even Australia, it is true, and it may be expected that before long the most protracted steam voyage from one port to another on the globe need not exceed a month. We are growing accustomed to extraordinary applications of natural and mechanical power. The hydraulic arrangements for lifting enormous weights at Great Grimsby and Birkenhead do not astonish us now. We have ceased to boast about the Bramah press, which gave to a 40-horse en-

gine the power of 1,400, and raised the tubes of the Menai Bridge, each nearly 1,000 tons in weight. The Great Eastern is as familiar, with all her vastness, in England as the giant pumping machinery for the Haarlem lake was to the dauntless industrial genius of the Netherlands. The blows of the Nasmyth hammer, the armor-plates of our iron-clads, the 20 miles an hour speed of the Holyhead packets, the 25,000 tons capacity of the Great Eastern, Krupp's monster artillery, the Cherbourg breakwater, the Bermuda floating-dock, the Liverpool docks, the arch over the Dee at Chester, the bridge of Niagara, the Fell Railway and the Mount Cenis Tunnel, the Atlantic and Pacific Railroad, the "artificial Bosphorus" connecting the Red with the Mediterranean waters—all these are testimonies to the tendencies of our epoch to attempt mechanical triumphs from the very thought of which the engineers of a former period—since the Cyclops and the Egyptians, at any rate—would have shrunk. The money for this Channel subway might doubtless be had; the materials, of course, would be forthcoming, and the difficulties of the work do not alarm the engineers of either country; the question, therefore, seems not far from being reduced to one of commercial calculation. But is a very serious question, notwithstanding, involving, according to the most moderate computation, an expenditure of £8,000,000, which, we should say, is merely fanciful, and as Gibbon said, when writing about Hannibal and his reputed passage of the Alps, a "sterility of fancy" in such matters is above all things else is to be desired.

Now, it may be taken for granted that, to nine-tenths of the people, at least in certain weathers, the passage from Dover to Calais, though brief in point of time and duration, is abominable. There is, naturally, a chopping cross-sea in that part of the Channel, due to conflicting tides, winds, and currents, and the steamboats feel the rolling motion all the more for being so small. The question has often been put, why are they so small? The inevitable answer is, because larger vessels would draw more water than the harbors on either side could command. They are all four shallow at low tide, are greatly encumbered by mud and sand, and are much affected by inconvenient winds. The question is, whether to improve them, or to diminish the necessity for their use. Hence the tunnel schemes, which are various. There was talk of iron shafts running up from the bed of the sea as means of ventilation. Then followed M. Favre's plan, in which the tunnel, like Mr. Remington's, was to be 100 ft. below the level of the sea-bed; shafts sunk through the water and clay were to furnish facilities for excavating the great hollow and supplying it with air; and the trains were to be propelled by atmospheric pressure. The subsequent ideas of Mr. Nicol and Mr. Austin were, the one for a tunnel lined with an iron tube, the other for 3 parallel ways cut at a depth of only 60 ft. below the weight of the water. But these imaginations were eclipsed by that of M. Thomé de Gamond, who proposed a tunnel ventilated by conical shafts, two of which were to be of such gigantic dimensions as to permit of winding roadways through their interiors, to a station buried 100 ft. down in the clay. Some one has astutely observed: "It is dangerous to laugh at engineers, for they have the knack of turning the laugh against us, by doing things which we have pronounced impossible;" nor are we speaking of impossibility in this case, when Mr. Hawkshaw, Mr. Brunlees, and Mr. Remington have recorded their opinions in quite an opposite sense. But the question is not entirely that of a tunnel. Mr. Batzman, whose authority will not be disputed, declared that he could construct a railway on the actual bed of the sea, and avoid the necessity of excavating beneath it. The proposal, however, was, so far as we remember, not altogether his own. More than 50 years ago, two distinguished Frenchmen, MM. Tessie de Mottray and Franchot, suggested that a cast-iron tube might be laid and secured across the bed of the Channel from Calais to Dover, of proportions to allow of wheeled vehicles to pass. Another Frenchman, M. Payerne, preferred masonry to metal, and wanted, by the assistance of the diving-bell, to build a causeway from shore to shore of brick or stone. Mr. Winton thought of a railway in an iron casing; Mr. Zerah Colburn would have sunk his tubes, put together on the land, in lengths of 1,000 ft. each; Mr. Chalmers developed a magnificent notion, which would cost £15,000,000; Mr. Cowan fancied an iron shell lined with concrete; and Mr. Page,

engineer of the new Westminster Bridge, declared for building on shore 8 conical shafts of iron, towing them out, sinking them, and filling in with concrete the space between an inner and outer skin. A lighthouse was to be erected at the top of each, while at the bottom would be, of course, openings to the tube, which would be constructed in ¼ mile sections, sunk, and joined by workmen descending in diving-bells. When some engineers asserted that men could not work under such an overwhelming pressure of water, Mr. Page affirmed that he could get rid of this difficulty with perfect ease. And so would Mr. Bateman, though in a different manner; he puts faith in a tube, but of a different construction, 13 ft. in diameter, and 4 in. thick, built up in sections, and put together within a peculiar kind of air-tight chamber, at the bottom of the sea, to be pushed on as the work advanced, by hydraulic pressure. But then arose a practical inquiry, on the part of a doubting man: "You would have 60,000 joints in your tube, any one of which might get into trouble, and what would you do then?" Which problem we are far from undertaking at present to solve. It is only a sketch of the idea, and its history, that we are offering. Then, there has been the plan of a floating corridor, so to term it, midway between the bed and the surface of the sea, calculated to float at a depth of 40 ft. or so, and steadied by mooring chains and anchors, with immense granite piers on both sides, at either end, and cork-screw staircases. The proposal is meritorious on account of its courage, and of little else. Much the same may be said of the Babylonian projectors who undertook to erect a bridge, right across, on 400 piers, at a stupendous height, or to carry one across the sea level, with pivot openings and drawbridges for the passage of ships, or to rear a structure for arches of 500 ft. span at an elevation beneath which all her Majesty's fleet could sail. We are bound, for the time at least, to dismiss many of these schemes as chimerical. There is, however, the project due, we think, to Mr. Fowler, of a steam floating bridge, in the shape of an immense flat ferry-boat, adapted for an exact touching, at particular times, of either shore, below certain towers, considerably advanced into the sea, where from an embankment the vessel could be raised or lowered, at any level of the tide, to an eveness with the railway. We have had similar plans roughly drawn by Mr. Chinie, Mr. Daft, Mr. Grantham, and Mr. Bridges Adams, besides one by Mr. Galloway on a less ambitious scale. The most elaborate of these, however, include the opening of at least two large and costly new harbors, whence the monstrous craft might be received and dismissed, works sufficiently easy on the English side, but presenting obstacles of serious magnitude on the French coast, since Calais is radically a bad port, while Boulogne is not far from being as unsuitable. The point selected by Mr. Fowler was at Andrecelles, situated between Boulogne and Calais, where there is deep water, no sand, and ample shelter. This would reduce the distance from London to Paris by 14 miles, the time occupied on the journey by two hours. Whatever may be the choice, in the end, of public opinion, it is not likely that the saying of Capt. Tyler will be permanently disregarded: "Frequently the traveller from India or America finds the British Channel the most unpleasant part of his transit, and he as often looks forward with more anxiety to the state of the Channel than to the heat of the Red Sea or the winds of the Atlantic." There can be no doubt concerning the absolute truth of this. But still more does it apply to the common passenger traffic across the Straits of Dover. The boats, as a rule, are confined, over-crowded, and ill-ventilated; women and children, in foul weather, are crammed into a cell, ironically called a cabin; the transport of merchandise is upon an equally unsatisfactory, if not discreditable system; more is lost, in value, on the quays and wharfs than in hundreds of miles of railway carriage; and how long will it be before some alteration takes place? We leave the grander projects, for a moment, out of sight, to quote some details of that which has been found practicable elsewhere. Boden-See, or Lake Constance, is a fresh-water lake, about 60 miles long by about 10 or 12 wide. It separates Austria, Wurtemburg, and Bavaria from Switzerland, and stops direct railway communication between Switzerland and those countries just as the British Channel does in the case of England and the Continent. "It was impossible to carry the railway round the lake, as the natural barrier which this forms is pro-

longed at its extremities by the impassable Alps"—impassable no longer, for this report was written some years ago. "Consequently, the goods traffic of Germany with Switzerland and the South of France, which is considerable, was exposed to delay by transhipment, to the great inconvenience of every one interested in it. Under these circumstances, Mr. Scott Russell, who had built the first fast steamer navigating the Boden-See, was asked by the Swiss Railway Company whether he could undertake to design a vessel by which railway trains and locomotives could be carried across, with the understanding that no machinery of any kind should be required to put the trains on board, except the ordinary locomotive engine." His prompt answer was in the affirmative. There were two small and shallow harbors, allowing of no more than 6 ft. draught. At each a structure was stationed for the traffic, nominally a ship, but answering all the purposes and having all the appearance of railway stations, with platforms, offices, and refreshment-room, double-decked, with two rudders, and independent paddle-wheels. The description goes on, the placing of the trains on board the ferry is a very simple operation. They are transfered by means of a bridge, suspended in the air by heavy weights, capable of adjustment to the rise and fall of the water, which, although it is a lake which is in question, has a periodical variation of about 10 ft. Carriages intended to cross the lake are left at the siding, which leads to the ship; the locomotive which does the ordinary work of the station comes and pushes the train on board, and, once there, special precautions are ready to prevent its breaking loose, and the whole operation takes rather less than 5 min. It may reasonably be objected that Lake Constance is not the British Channel. It is not an enormously over-crowded maritime highway; it has no Atlantic billow and no heavy ground swell; but it has the short, sharp, chopping waves characteristic of the Dover Straits. Says Mr. Scott Russell, "the advantage of taking your bed-carriage in London, and not having to leave it until you awake in Paris, need not be enforced." Between the politicians who maintain that "the thin streak of seasickness" separating our island from France is our natural fortress, and the tourists who want it abolished, what can be said? For ourselves, we have nothing to do with the politicians, and trust that, in the long run, the engineers may decide the question among themselves.

RAILWAY DEVELOPMENT, ENGLISH AND FOREIGN.

From "The Builder."

We have arrived at a period of crisis in railway development. It is not that any new impulse has been given either to our mechanical skill or to our commercial prosperity. It is not such a start as was due to the first triumph of the genius of Stephenson, or the first practical outcome of the business capacity of George Hudson. It is due to no single event of magnitude; although the successful accomplishment of some of the greatest feats of engineering have recently been commemorated. But the general result of the engineering of the last 40 years, when undisturbed by the avidity of speculators, is such as to indicate further progress. From all parts of the world the same signs are manifested. The Alps no longer exist as a mountain barrier necessary to be crossed in the route from Paris to Brindisi. The Isthmus of Suez no longer forms a material bar compelling our ships to double the Cape of Good Hope. The eastern and western shores of the great American Continent are linked together with an iron band. And projects for a direct line of communication from our old *tête de pont*, Calais, to the capitals of our Indian Empire, are assuming more than a visionary probability.

Connected with, or at all events most significantly contemporary with, these wide-spread fruits of the skill and patience of the civil engineer, is the march of a movement in our railway economics at home which has long been urged by one or two far-seeing men. Two of our largest railway companies, one of them the father of all our iron lines (for it has absorbed its own parent, the Liverpool and Manchester), the annual income of which amounts to a seventh part of that of the

State itself, have agreed to make common cause, and to share a common purse. The example set by the London and North Western and Lancashire and Yorkshire railways cannot fail to be widely followed. It has, of late, become pretty clear that the main enemies to railway dividends have been railway directors. The spirit of actual hostility, the desire to injure a rival undertaking, at whatever cost, has been, perhaps not extinguished, but rendered practically powerless, by the absolute necessity to stop reckless outlay, and to close capital account. This was the first victory gained by the shareholders over the boards of management. But with new lines abandoned, and Parliamentary contests suspended from pure inanition, the individualizing spirit still ruled the several Boards. Thew hole some, practical, eminently paying idea of a great railway federation was scouted. It may be extremely unjust to attribute to railway directors, as a body, any but the best and purest motives. Still, human nature is human nature ; and any steps that might tend to destroy the power, patronage, and position enjoyed by the chairman and leading members of the various boards of directors could not fail to excite an instinctive repugnance on their part. Thus the period of actual waste, of flinging away money by handfuls in the construction of unnecessary lines, has been succeeded by a period of passive waste. Attention has been given, indeed, with more or less wisdom to the development of the resources of individual lines. But the immense advantage to be obtained by the common adjustment of all details of the traffic of the country, by a system of through tickets, by the abandonment of duplicate trains and of the general ignoring, by one line or set of lines, of the existence of their neighbors, has been hitherto obstinately neglected.

How great an immediate return to the shareholder is to be secured by a wise and practical federation, it is not easy to tell. In the case of virtually rival lines, such as those which have so long wasted the great resources of the south-eastern district, the result would probably be the most immediate. Where there are two or three routes available between the same *termini*, the arrangement of the trains on the several lines so as to quarter the day is a duty of the most obvious nature. It is one that has been almost invariably neglected. Yet the saving in the unnecessary trainage miles run that could thus be effected, without any loss of total revenue, would form a very appreciable item in the half-yearly accounts. Thus far the mere common-sense idea of self-protection at which our coach-owners, after a good bout at competition, usually arrived, might have been thought enough to render Bradshaw a volume of much greater unity of purpose than is actually the case. But then, it is true, the competition for the best time of the day—for the 9 o'clock morning train, for instance—might require some mode of arbitration. Everything, therefore, points in the direction of what our French neighbors would call syndicating the earnings of the lines. A common purse, to the common advantage of all, will lead to unity or community of management. That, before very long, some organized federation of our immense traffic companies will be carried out, there is every reason to believe.

While the actual saving thus to be effected is large, it is nothing as compared to the stimulus that will be given to our internal traffic by the removal of the present petty and unnecessary obstacles. The politico-economical theory of supply and demand may be said to be inverted in the history of our English railways. It has not so much been the case, that the need of men to travel has led other men to supply improved means for so doing, as that the supply of accomodation, far more extensive and available than its projectors originally contemplated, has developed an enormous capacity for internal circulation, both of passengers and of goods. Every railway journey taken by any individual may be thought to lead to other journeys by other individuals, and to a corresponding increase of activity in postal, telegraphic, and mercantile interchange. Whatever may be the limit to this self-augmenting activity, there are no signs that we have attained or even approached it. When we see what has been effected by every instance of well-planned junction, and judiciously extended accommodation, we cannot doubt, that if the union of design and aim, for which the physical means for the most part already exist, be adopted by our leading companies, a great and rapid increase in traffic of all kinds will be the immediate result.

This result will, in the first instance, benefit those who may be thought most entitled to the advantage—the holders of the ordinary stock and original shares of the railway companies. For the improvement which has followed a few years of failure in the railway system has been such as to lead us to this point. Preferential charges are now, as a rule, fully discharged out of profits. Debentures, debenture stock, and preferential shares of all kinds, are already satisfied. The surplus profit belongs to the original shares; and as the proportion of capital over which every rudiment of new profit has to be spread is so much less than the gross capital by aid of which the earnings are effected, the rise of dividend will be very appreciable. The last half year has shown this to be the case. The summer dividend of 1872, if the one-purse system shall have been extensively adopted by that time, may recall the golden days of 1845.

Our internal communication, within the memory of not more than two generations, have experienced three great eras of improvement. We anticipate the arrival of a fourth. The first of these was the great change wrought in our highways by the adoption of the simple, common-sense plan which Macadam first induced the Bristol Road Trust to introduce, although in the plains of Apulia it had been in practice from the time of Trajan. As far as the employment of horse-power, for speed and for luxury of travelling (though not for the conveyance of heavy weight), could be available, the Shrewsbury and Devonport mails and fast coaches may be said to have attained the best conceivable results. We had then a lull in the improvement of traffic. For some years we were content to maintain a rate of excellence that was nowhere to be met with out of England. Then came the unexpected triumph of "Puffing Billy" and his friends. Not knowing what to do with the waste high-pressure steam, the engineer turned it up the chimney, and found that, in its hasty escape, it afforded him the means of flying a mile in a minute. Steam volunteered to do more, after its actual calculated task was done, than had been asked from it in the first instance. The power of producing motion by pressure had been matter of calculation, the power of generating heat by rapid blast was an unexpected godsend. This blast was the very life of the railway.

Intermediate, to some extent, between the latest improvement of the high ways and the substitution of iron tracks for the main through roads of the country, was the introduction of water-carriage for heavy merchandise. We are not among those who consider that we have heard the last word as to canals. In the first place, long lines of this nature exist, well laid out in many cases, and have to be kept up, or to be destroyed at a considerable expense. Thus the actual cost of water carriage is the lowest required by any mode of transport. The point where the canal is at a disadvantage is speed. So long as we stick to the towing-path the rate of transit is necessarily slow. But an age which has seen the application of steam-power to an object so refractory as that of breaking up the earth over a large area—a duty that might well have been thought beyond the function of machinery—is not likely to fail in the endeavor satisfactorily to apply steam-power to canal towage, when once it appears likely to pay. In fact, the plan of what was called many years since, the "messenger propelling engine," seems likely to meet every requirement. In any case the improvements of the past 20 years have been such as to lead to the anticipation that the application of steam or other mechanically produced power to machinery of all kinds is yet only in its infancy, and that what we can now do by mechanism is but a very small part of that which mechanism is destined to effect. At present, however, we can only speak of canal transport as among the abandoned improvements of the past—one of the three great steps made by our engineers in the conduct of internal traffic—viz., good roads and good coaches, good water-carriage, and main trunk railways.

The stimulus that will be given to the railway system by linking the networks of the various great companies together in one organic whole, must cause, not only the great increase of traffic due to this facilitation, but the prosecution of what may be called the Secondary Railway System. Isolated attempts at this development have been made for some years past, with more or less success. We have had reports of the cheap construction and economical working of light railways in India, Norway, and elsewhere, that are perfectly

conclusive in the opinion of engineers. We are witnessing the attempt to introduce tramways into London, with, apparently satisfactory results in a commercial point of view, although the questions of the interference with ordinary road traffic, and of the effect likely to be produced on the rental value of the principal thoroughfares, cannot be regarded as decided. But what is desirable, and will, no doubt, follow, is, that the service of those parts of the country which are as yet only very partially benefited by the railway system, shall be regarded as a serious national object. Call them light railways, tramways, or what we like, we must have the means of reducing the running friction which forms so large a portion of the expense of land carriage placed at the disposal of the country. The important point is, that the method of effecting this object should be so decided by the best professional experience, that, when the wind of public favor sets in that direction, we should not have a repetition of the madness of 1845—every man's hand against his neighbor—for the construction of his own speculative tramway. A well-constituted railway federation, giving the weight of its sanction to the most available lines of subsidiary railway, in the first instance, may save us from this disaster. At all events, it is not easy to see what other check will be available, as Parliamentary legislation hitherto has only intensified the evils of competition.

The question naturally arises, can the control of the internal traffic of the country, if centralized, be safely intrusted to any other hands than those of the State? Out of England the answer would be simple. Roads and highways have always been regarded as the special charge of the administrative powers. Postal and military exigencies alone require the unfettered action of the Executive; and for the Postmaster-General or the Minister of War to have to apply to the Railway Director-in-Chief for the means of sending dispatches, or moving troops, could never for a moment be tolerated in a duly organized State. But it would be unsafe to make any prophecies as to England, however probable it may appear that railways will be dealt with by and by as telegraphs are now being dealt with. A country that allowed a mighty Continental empire to remain for a series of years under the rule of a trading company may well allow any commercial interest to grow, bit by bit, to Imperial proportions. Again, much of the battle as to the conveyance of mails and troops has been already fought out in detail, and in the application to the Legislature for powers to render the proposed federation not only legal but binding, opportunities would be afforded for the protection of the public interest. With the impression, then, that the ultimate form to be assumed by our railway management will be that of a department of the Government, we think there is no such certainty in the matter as to allow of any very practical inferences being drawn on the subject.

There is, however, a point of view of no small importance which is not only national, but international. Our insular position prevents us from being bound in the chain of that common interest which unites, or ought to unite, the railways of the Continent. But our interest in the proper development and management of those railways is scarcely inferior to that of the States through which they pass. Considering our connection with India, the state of the line over which the Indian mail is transmitted to Brindisi, is hardly less a matter of English interest, than the condition of the Holyhead route itself. Now there has long been a determination evinced by the directors of the French railways to throw every possible obstacle in the way of a route which shortens our journey by 60 hours, but which avoids Marseilles. The opening of the Mont Cenis Tunnel brings this matter to a crisis. The Italians have their 30 miles of railway up to the tunnel complete; the French 10 miles are all in disorder. Only an omnibus train, stopping so often and so long as to weary the patience of Job himself (if the much enduring patriarch had taken a ticket), is allowed to crawl towards the perforated barrier of the Alps. The tunnel is complete; but, if French policy can avail, it will be rendered no thoroughfare.

We require a body of men, or a duly authorized individual, to deal authoritatively with this and with similar questions, on the part of the commercial interests of this country. If left to diplomacy to settle, the dispute will unavoidably drag on for years. It is not by way of flinging a stone at our noble and patriotic

representative in France that we say so; but a minister has his hands very closely fettered when he is called upon to advocate any commercial interest, and especially when, as in the present case, peremptory settlement of the matter must be demanded, on pain of making immediate arrangements (which are perfectly feasible) to avoid France altogether for the route of the Indian mail. That despatch must and will take place from the proper point of the South Eastern Continental system of railways, namely, from the old Roman port of Brindisi. Our shortest way to this point is through the Mount Cenis Tunnel. But other routes are open to us, and the day of Marseilles, as the sailing port for India, is over. If the French will not see this—which is not unlikely—we do; and we require machinery to act nationally in consequence. It is now possible to effect a great saving in the transit of the Indian mail, and it concerns us deeply that this should be at once carried out.

There is one question which we are much surprised to find still not only unanswered, but even unasked. It is a question not, perhaps, of any great commercial importance, but of deep interest to the scientific world, and to the profession of the civil engineer. How did the two lines of the Tunnel meet? We all know that the junction was happily effected, and that the line is now complete and in working order, through the bowels of the Alps.

We offer our most sincere and hearty congratulations to our Italian *confrères*, the engineers Grattoni and Grandis; and only regret that Sommeiller died just too early to witness the triumph. But we must be excused for asking for details. What was the actual measurement—decimals, inches, feet, or yards—by which the two centre lines, started 8 miles apart, were found to differ from absolute coincidence when they met? What was the divergence in azimuth, and what was the difference in level? The more or less can hardly affect the well-earned fame of the successful engineers. But the gratitude due to their skill and tact will be increased if they furnish an accurate reply to a question which, though exclusively technical, has a deep and lively interest for the profession in this country, and will furnish a piece of valuable information in the history of the important public works of the present century.

THE STEVENS INSTITUTE OF TECHNOLOGY.

(*Continued from page 536.*)

The course of instruction to be given at the Stevens Institute of Technology, as stated by the Trustees in their "Announcement," is intended to be such an one as will "fit young men of ability for leading positions in the department of mechanical engineering and in the pursuits of scientific investigation, from which this and all the sister arts have derived and are daily deriving such incalculable benefits." it is therefore arranged with a view to afford "a thorough training in the elementary and advanced mathematics in so far as these are useful means of investigation and work, and not themselves the ends and objects of labor." It also includes very thorough courses of instruction in Physics, Chemistry, and Metallurgy, throughout which the student will be expected to do real work in the laboratories, pursuing experimental investigations bearing upon the principles taught, and in the course of which he will be directed in the field of original research.

In the workshop he will be taught the use of tools, and will be expected to spend a fixed proportion of his time in acquiring the details of workshop practice.

Languages and literature are given a deservedly important place in the college *curriculum*.

The full course is four years in length.

The first two years are properly preparatory, the student taking the usual college courses in science, with, however, a careful adaptation of their details and of the methods of instruction to the requirements of the advanced, and truly technical courses of study.

The instructors are expected to point out to their classes with scrupulous care, the important bearing of the principles of pure science upon the phenomena of every day life, and to impress upon them those

principles which become most important and useful in the succeeding years of study, by every possible means, whether of simple tuition or of practical illustration.

At the close of the first two years, the student having completed the usual elementary courses of mathematics, chemistry, physics, modern languages and literature, and of mechanical drawing, he is prepared to enter upon the advanced courses in science and for technical instruction.

In the languages, during the last two years his reading becomes to a considerable extent technical, and it is given such a direction that it may be made useful to the student in the line of the special work which he will have to do in post-graduate years.

In the chemical laboratory, the student engages, under the direction of the Professor, in the study and practice of analysis, qualitative and quantitative, and in the investigation of practically useful and important chemical problems, and in experimental investigations in some of the many promising directions that are continually presenting themselves in the practice of the engineer and in the experience of the man of science. The analysis of useful ores, and of the hundreds of materials used in the arts, detecting their impurities and their adulterations, or proving their excellence, and revealing the valuable elements in useful compounds or determining the best proportions of combination, are some of the applications made of the time spent in this department during the advanced course.

In the Physical laboratory, the student receives such an advanced course of instruction, such as is very rarely given in even the best of American colleges, and this constitutes a very important part of the general course.

He is, by a two years course of instruction in the actual use of physical apparatus and in the prosecution of experiment and research, familiarized and impressed with the physical properties and laws of matter. The instruments and methods by which those properties are revealed and by which those laws are demonstrated, are exhibited to him, and at the same time he acquires a sleight in the use of apparatus that is of great value in itself, and, also, as a mnemonical aid.

Habits of accurate observation and logical deduction acquired by such a training in precise observation and investigation, will tend to make the knowledge attained exact and ineffaceable, and the education of the mind and the hands to work together, prepares the student for similarly effective investigations in his subsequent professional life.

In pursuing this laboratory work, the student receives from the Professor an outline of the special research to be undertaken, and with it a minute description of the construction, use, and adjustment of the instruments needed in the work.

He then goes on with his work and the results of his labors are carefully preserved, and, at the proper time, if of general interest, published.

The Trustees state their willingness to extend the facilities for such work which are possessed by the Institute, to all competent investigators, upon very moderate terms, whenever important investigations are proposed to be undertaken.

Prof. Tyndall says: "Half of our book writers describe experiments which they never made, and their descriptions often lack both force and truth; no matter how clever and conscientious they may be, their written words cannot supply the place of actual observation." He might have added, "and of actual manipulation."

The students at the Stevens Institute will not be of the class referred to.

It is at the close of the second year, also, that the student is expected to be prepared to enter upon the course in Mechanical Engineering.

He first takes up the subject of Applied Mechanics, and studies the nature, uses, strength, and methods of preparation and of preservation of the materials used by the engineer. He is made familiar with the theory of machinery, and is taught the principles of tool-making and tool-using, and of design, in their application to machinery and mill work.

He is given instruction in the proportioning of cams, gearing, and other elements of machines, and is then made to design and proportion pulleys, levers, windlasses, pumps, and others of the simpler machines.

He has pointed out to him the modifications of design which become necessary in consequence of difficulties in pattern

making, moulding, forging, or finishing and fitting up the several parts of the machine.

He is made familiar, as far as possible, with the cost of stock and of labor, and is expected to calculate the amount of these items in special cases.

The Prime Movers are made the subject of study and discussion during the last year of the course, and specially careful and extended consideration is given to the principles of the steam engine and to all the details of its design, construction, cost, and management, according to the best and most recent practice.

At the close of this course the student is expected to read a thesis upon a professional subject, illustrated, where necessary, by drawings, and his success in this will have an important use in assisting the faculty to determine what success the student has met with in the endeavor to profit most fully by the instruction received in the professional course, and to whom should be offered the best of the business positions which are placed at their disposal.

The course of instruction in Drawing extends through the whole four years, and during the last two years, is intended to be a parallel course with that of Engineering, being directed in such a manner that while studying the elements of machines, the student, who has previously learned to use his instruments skilfully, may make drawing of those machines, and when studying the more complex machines and the prime movers, the student will devote his time in the drawing room to the same subject, the two courses being thus made to aid each other as far as possible.

The President of the Stevens Institute is Dr. Henry Morton, well known to the public generally as a successful lecturer, to physicists as an original investigator, and among engineers as, for a considerable time, and until recently, the editor of our esteemed contemporary, "The Journal of the Franklin Institute."

The chair of Engineering is filled by Professor R. H. Thurston, of whom the "Providence (R. I.) Journal" says, in an article descriptive of the Stevens Institute: "He acquired his practical knowledge and training here in Providence, with Messrs. Thurston, Greene & Co. and Thurston, Gardner & Co., his scientific education at Brown University, his experience in the management of steam engines and machinery here and during a ten years' service in the navy as an engineer officer, and his experience as an instructor by a five or six years' term of duty as 'A. A. Professor and Lecturer on Natural Philosophy,' at the Naval Academy."

Manufacturers are doing much to assist Prof. T. in making his course a success by contributing liberally drawings and models of their machinery.

In addition to those already named, A. S. Cameron and W. D. Andrews promise models of their pumps; Messrs. Babcock & Wilcox and Richards, Loudon & Kelly send drawings; Cooper & Hewitt offer samples of their iron and steel manufacture, and dozens of other well-known firms promise similar favors.

Prof. T. also acknowledges the kind assistance of Prof. Rankine, E. B. Martin, F. de Lesseps, and other Transatlantic friends of technical education.

Dr. A. M. Mayer, as Professor of Physics, opens the large physical laboratory above described. His long experience as an instructor, and his familiarity with the best methods of research as evinced by the success of his original investigations, published in our own journals and quoted abroad so frequently, will render him an excellent coadjutor with Professor Morton in the inauguration of this most important branch of collegiate work.

Professor Albert R. Leeds has accepted the call to the department of Chemistry, and has brought with him his cabinet of minerals, turning them over to the Institute. Prof. L. was formerly Lecturer on Chemistry and Geology before the Franklin Institute of Philadelphia, and still earlier at Haverford College, and in the Philadelphia Dental College, which institution at that time and since has achieved a very marked success.

Lieut. Col. H. A. Hascall, U. S. A., has resigned his commission and has retired from his professorship at West Point, to accept the chair of Mathematics in the Stevens Institute, and his resignation will be much regretted by his army friends and pupils, while the authorities of the Institute have equal reason to congratulate themselves on securing him in that very important department.

Col. Hascall has been prevented by ill-

ness from entering upon his duties promptly, but his place is ably filled by Professor R. H. Buel, lately Assistant Engineer on the Tehuantepec and Nicaraugua Ship Canal Survey, and who was formerly an officer of the U. S. Naval Engineers and an instructor in the Department of Natural and Experimental Philosophy of the Naval Academy.

Professor McCord, a graduate of Princeton, a gentleman of considerable experience as a mechanical engineer, and who has done much of his work under the eye of Captain Ericsson, is Professor of Mechanical Drawing. Professor Kroegh, formerly of Lehigh University, is Professor of Languages and French and German Literature, and Professor Wall, the able Director of the Stevens High School—the preparatory school of the Institute—takes charge of the Department of Rhetoric and English Literature.

With a large, well-designed, and substantial edifice, a carefully selected stock of apparatus, and fine corps of Professors, the STEVENS INSTITUTE OF TECHNOLOGY makes a splendid start as a pioneer School of Mechanical Engineering, and we may feel confident that the success of its graduates in the practice of their professions, whether of science or engineering, will find its limit only in that of their own industry and talent.

SCIENCE IN PLAIN ENGLISH.

BY PROFESSOR CHARLES A. JOY.

From the "Journal of Applied Chemistry."

Under this heading I find in "Nature" an admirable article by William Rushton, of Queens College, Cork, which I propose to make the text of a few remarks upon the present condition of scientific education in the schools of the United States. Mr Rushton admirably epitomizes the state of things in England in the following sentence: "Some schools have admitted science on about the same terms as dancing—that is to say, they give 1 or 2 hours a week to it; or, they may even admit it on equal terms with French, but it is generally made quite subordinate, and while classics are rewarded with high honors, science receives few distinctions." We must admit that what he says of English schools applies equally well to our own. Does anybody know of a preparatory school in the United States where instruction in science is given on a systematic plan by teachers especially fitted for the work, and with well-selected apparatus and judicious text-books, and where an equal value for excellence in science is given to pupils as for mathematics or the languages? There are doubtless some such schools, but it is my misfortune never to have heard of them. The truth is, there are few teachers. The custom in this world of studying everything else but the world we live in, which has been handed down to us from our ancestors, has precluded the possibility of anybody being fitted to teach the natural sciences excepting the few who have had the energy and the means to overcome every obstacle, and to learn something; and they are so rare that they are not to be had for ordinary schools. We are now in a fair way to acquire considerable knowledge of the planet Mars, its climate and physical condition; and it may be that we shall some day be favored by a visit from an inhabitant of that distant world. The arrival of such a visitor would be rapidly heralded over the land, and he would be introduced to our best society, to the leading men of education; and as he would doubtless be possessed of an inquiring turn of mind, he would have many embarrassing questions to ask. He might address the inquiry to the gentleman on his right at the public dinner, which would be sure to be given to him, as to the composition of the crust of the earth; or he might ask what the glass windows were made of, and what form of light shone through them, or the water on the table and the air of the room might absorb his attention. If the respondent happened to be a University bred man, the chances are 10 to 1 he could not answer a single question; he would be forced to say that the study of the language of a people formerly occupying a small portion of the globe had monopolized all of his time, and prevented the acquisition of a

knowledge of any of the natural phenomena around him; he might in fact have more knowledge of Mars than of the earth. It is probable that our visitor would be slightly astonished at the ignorance of the best educated members of the community. I do not know that we are bound to prepare ourselves for the approaching visit, but the very suggestion of it ought to startle us a little out of our propriety, and make us review the course of instruction we have pursued for so many years. As long as the requirements for admission to college are left just as they are at present, all persons who expect to go to college must follow a prescribed course, or be found wanting. The teacher in a preparatory school knows that the pupil can attend only a certain number of hours, and to get up his task for admission to college nearly all this time must be devoted to classical studies. There is no time left for science, and it is not taught. This state of things has led to a violent controversy on the part of the advocates of the two systems, and the question appears to be no nearer a solution at the present time than it was many years ago. The advocates of classical training will not yield an inch of ground, and the scientists are equally firm. It is a pity that some compromise cannot be effected, as a knowledge of Latin and Greek is of great value to the scientific student, and ought not to be omitted. And as the classicists now have the colleges in their power, would it not be well for them to recommend a knowledge of language rather than of grammar, and a facility of reading generally instead of prescribing the precise number of chapters and verses? If the teacher of Chemistry, for example, were to insist upon the students studying 100 pages of Miller, 50 pages of Roscoe, two books of Gerhardt, the correspondence of Lavoisier, and the life of Berzelius, before presenting himself for examination, he would be looked upon as slightly deranged; and yet this is precisely what is done by our classical friends. A chemist can tell in half an hour whether the candidate is prepared to go on with a certain class; and he cares not how, when, or where the applicant obtained the knowledge. Not so our classical friends; they insist upon chapter and verse as if there were a charm in the prescribed number—and by so doing they do great harm to our schools. A friend of mine desired to put his son at a select school, and had a long conversation with the principal in reference to the studies he would have to pursue in order to fit him for college. The principal had the experience of 30 years in his calling, and knew precisely what was required. He produced his scheme of hours, and convinced the parent that in order to fit his son for college it would be necessary for him to devote a certain number of hours to the reading of a prescribed number of pages and verses of Latin and Greek; and to do this no deductions could be safely made. He showed that the average attendance of boys was about 6,000 hours, and by assigning to each hour its particular work, if not interrupted by accident or illness, the pupil would be able to come up to the prescribed standard. My friend tried to see if a few minutes could not be gained for a small amount of science, but the teacher, with his experience of 30 years, was inexorable, and he could not crowd in a knowledge of this world into the course of studies even edgewise. It has been sometimes said that the most ignorant members of our community are our men of education; and after looking over the scheme of studies which the victims of liberal education are obliged to follow, the paradoxical remark would almost appear to be true. It may therefore be asked what change the advocates of reform would propose? I cannot attempt to answer this question for all parties, as there is little uniformity of belief on the subject; but it may be well to state the case of a prominent party in the modern agitation. We have a large class among us who admit the culture to be derived from the study of language, and who would not on any account banish Latin and Greek from the curriculum; but they would remove that study to a later part of the course and replace it by scientific subjects. They think that those subjects which cultivate and strengthen the powers of perception, observation and judgment, should be taught first. They would instruct the youth in a knowledge of the laws of health or physiology; they would have him know something about plants, animals, minerals, and the commonest laws of chemistry and physics, so that if the pupil is compelled to leave school at an early age, he would know how to take care of mind and body, and be enabled to

turn his knowledge to some account. They would commence the study of Latin and Greek at a period when the mind is more mature, and thus avoid the enormous waste of time, the bad habits of droning over lessons, and the monopolizing character of the present system. There are so many instances of persons who commenced the study of the classics at mature years, who have excelled all others, that the advocates of postponing languages to the latter part of a boy's course appear to be justified in their claim. If the study of Latin and Greek could be commenced after the student enters college, it is believed that more real progress would be made in the four years of the college course than is effected under the present arrangement of devoting ten years of a boy's life to this study. This is the compromise that many good men advocate. They wish the preparatory schools to be wholly given up to mathematical, scientific and English studies, and to have the colleges assume the charge of the classics. Instead of devoting every hour of the preparatory course to languages, they would give the time to the sciences, and they would demand a knowledge of the general principles of science as a requisite for admission to college. This would be turning the tables entirely, and would afford scientific men a chance to try the effect of the modern education. The other side have had it all their own way for a long time, and it would appear to be no more than fair for them to let people of different views have a chance. Such a radical change as this cannot be accomplished at once. It would demand immense moral courage on the part of the trustees of a college to expose themselves to the cry of lowering the standard of study. They would have the alumni of existing institutions and the prejudices of the whole community against them, and it would require a generation before the majority would become reconciled to the new order of things. Another obstacle would also arise at the outset, and that would be the difficulty of securing competent teachers of the natural sciences. It is this obstacle that has stood in the way of the introduction of the study of science in our schools. There are far too few teachers. To surmount this difficulty in the city of New York, a normal college for females and a free college for males have been established; and scientific schools have been founded in all parts of the country. These institutions are destined to work a great revolution. As soon as they have trained a sufficient number of teachers, we shall find our public schools affording a better education than at present, and their example will have to be followed by the owners of private schools, who desire to keep up with the progress of the age. What we want is science taught in plain English, and there is every prospect of our speedily attaining the desired end.

ON THE SANITARY ADVANTAGES OF SMOOTH AND IMPERMEABLE STREET SURFACES.

By EDWIN CHADWICK, C.B.

From "Journal of the Society of Arts."

The condition of the surfaces of the streets, courts, and alleys of the metropolis formed an important topic of examination under our Metropolitan Sanitary Commission. The state of the unpaved districts; the noxious emanations from the subsoils; the absorbent surface mud; the stagnant pools containing dung and other decomposing animal and vegetable matter;—the filth collected on the person and on clothes derived from it, and taken into the habitations, powerfully affected the cleanly habits and the health of the population, especially of the children, who are always out playing upon such surfaces. In places where self-cleansing house drains and sewers have been brought into good action, and where the death rates have been reduced, but where some amount of typhoid and foul-air diseases yet lurk, they have been found to be very much confined to those streets where the surface is unpaved and badly cleansed, and the subsoil sodden with foul matter. The pernicious effects of these conditions are, as might be expected, most severe on children, from their being, by reason of their lower stature, nearer to the ema-

nations, and from their being more weakly, and thence susceptible to their influence. The sanitary condition of the then best paved streets was very bad, presenting "seas of mud" in winter, and in summer giving off "clouds of dust," which settles on the clothes, the skin, and the hair, and gets into the lungs. The worst is that the dust is generally dung dust. The experiments of Professor Tyndall go to prove that the whole of the visible particles floating in London rooms are of organic origin; and other experiments have stated that horse-dung furnishes the greatest proportion of them. In some of the leading thoroughfares as much as a cart-load of dung was removed daily from every mile of street. In the City there were, I was informed, about one hundred loads of surface matter, chiefly dung, removed daily. To persons coming from the rural districts the streets frequently smelt like badly cleansed stable-yards.

At the first General Board of Health, in times of severe epidemic periods, we directed that the affected districts should be carefully and thoroughly surface-cleansed. This was directed to be done by jets of water thrown by engine power, or from the mains where water at high pressure was available; but in many districts the jets, in clearing away the dung deposits from the interstices of the paving, often also washed away or tore out much of the supports of the large stones, and even, where they were firmly jointed, left much objectionable surface water and evaporating moisture. The only remedy available in some excrement-sodden districts was to cover the street surfaces over, for the time, with fresh mould or soil, which, when it was done, made the people feel, as they said, as if they were living in another atmosphere.

It resulted from our examination that, by some better mode of paving, which we hoped might be obtained—than that of large stones put down to resist the shock of heavy carriages, which again entails the construction of heavy carriages to withstand the shock of the large stones—and by lowering the gradients, and by the introduction of tramways at some points, half the usual horse power might be saved—a saving of great importance in itself in the economy of traction and of intercommunication; but, in our view, of peculiar sanitary importance as a diminution of half the horse-dung and its noxious evaporation, and the injury of the dust and dirt, and a reduction of the expense of the surface cleansing of the streets.

I certainly expect that the saving of horse power, from the paving with the new material, of peculiar hardness, as yet unsurpassed, and, as far as I have seen, unequalled, by anything of the kind—the Val de Travers asphalt—will be more than one-half of that power, and consequently a saving of more than half the dirt and dung in the streets, and that this pavement will nearly equal the tramways in this respect for public vehicles, whilst it will exceed tramways in general convenience, especially for all sorts of private carriages. Sir Joseph Whitworth, who has studied street economy and the means of street cleansing, and who is much struck with the new material, tells me that he anticipates that when extensively adopted, it will make way for the hot-air engine, with india-rubber tyres. A colleague of mine, of the Institute of France, who for the last 10 years has ridden over a street paved with the Val de Travers asphalt in Paris, speaks of the great comfort in riding over it. The horses on becoming accustomed to the tread, he says, do not certainly slip more, or so much, and when they fall do not tear their knees as on the old pavements.

One advantage of gravel soils is the rapid discharge of surface water, and immediate dryness after rainfalls. This advantage is possessed in a high degree by the impervious and even asphalt surface.

There is one peculiar evil attendant on the old systems, which is the noise, the rattle, and the vibration of the traffic over them, to which strong people become accustomed, and do not mind, but from which weakly and ailing people suffer very much, being sometimes obliged to leave town to avoid it. The removal of the sick over these paved roads is often attended with considerable danger from the rolling and shaking. At our General Board of Health, it was strongly represented that great injury, often fatal, was inflicted by the removal of some large classes of sick in common cabs, or in other common conveyances, over paved roads. Exhortations were prepared for popular circulation, that, on the occurrence of accidents in the

streets, attended by the fracture of limbs, it is of the greatest importance that patients should not be put into any common conveyance for their removal, but should be allowed to remain where they fall until a surgeon can be brought to direct special and safe means of removal by stretchers. In relation to the action of granite pavements on healthy persons, a professional friend declares that the loss of what he calls "brain force," from the vibration and disturbance of the nervous system in much riding over the old carriage pavements, is much greater than would be imagined. We know that for ladies of the well-to-do class, it is found necessary at times to spread straw over the street, to prevent the vibration, and deaden the sound of carriages. With a pavement of this very remarkable new substance, which gives, with great tenacity, a sort of elastic surface—hard and inodorous alike in summer and winter—it is very much as if tan were always laid down before all the houses of a whole line of street. Tradesmen in Cheapside testify, as one characteristic of it, that without shutting their shop doors, they can now hear their customers, and can make themselves heard by them without shouting, as heretofore, to overcome the noise of the carriages over the granite pavement. Those living in such streets can now keep their windows open with little annoyance either from noise or dust.

The macadam roads, in cities of great traffic, may be said to be huge stone mills for grinding granite dust. Some notion of the extent of the work done in this way in the metropolis may be formed from the fact that there are annually imported, and used there, 650,000 tons of granite, of which it is estimated that about 100 tons are imported in cubes, and that the rest is used as macadam. In addition to this material, large quantities of flint, and also other stones imported as ballast, are used. In Birmingham, 50,000 tons of granite are put on the roads every year. Every year, therefore, so many tons of granite are ground, in dry weather, into dust with dung, which the winds carry about, and in wet weather into mud. The wear of the macadam roads is from 1 to 4 in. or more of granite annually. Westminster-bridge, it is stated, requires annually a coating of at least 5½ in. of the very best granite that can be got. The wear of any smooth road, by reason of the very smoothness, is comparatively inconsiderable, an example of which, I am informed, may be given, though of a street of secondary traffic, compared with our chief thoroughfares, the Rue Bergere, in Paris, where the result was observed. The street was laid with 2 in. of Val de Travers asphalt in 1854, which was lifted in 1869 when it was found to be reduced to 1⅜ in., but chiefly by compression, for it had, during the 15 years, lost only 5 per cent. in weight. I am informed that similar results have been obtained in Threadneedle street, for the time the new pavement has been down there.

We found that those granite pavements very injuriously affected the working of the sewers. When the granite dust is washed by rain into the sewers, it often forms an indurated surface, only to be loosened by the pick, and to be removed at much trouble and expense. This sometimes occurred, even with tubular glazed pipe sewers. To obviate this evil, we had traps carefully constructed at the mouths of the gulley shoots to arrest the granite detritus, for which, however, in times of storm or heavy rain, they proved to be insufficient.

When the new granite or flint material for macadam is first laid down, it is a cruelty to horses, and a barbarism as respects carriages and carts, to impose upon them the labor of crushing it. The steam-roller is a relief to them, and an economy in getting a somewhat better surface, though still, to some extent, a permeable one for dung. But this implement, it is now found, aggravates waste and evil of another sort, produced by the vibration from heavy traffic. One great inconvenience in those streets is the frequent breaking up of the pavement for the repair of gas and water pipes. I found from my own inquiries that the leakage of those pipes was very much proportioned to the heaviness of traffic, and was inconsiderable in the by-streets and districts of little traffic, the vibration of the heavy traffic perpetually shaking the lines of pipes and loosening their joints. The escape of gas, besides being a waste—which in some districts was stated to amount to as much as 30 per cent.— was attended by sanitary evil in the pollution of the air, and even in some cases of the drinking water. So great in some districts was the

saturation of the subsoil with gas, that, where the water supply is on the intermittent system, and the pipes are alternately full and empty, the water-pipes were often filled with gas sucked in from the substratum through the loosened joints when the water was drawn out of the pipes. Mr. Milne, the engineer of the New River Company, to demonstrate this condition to me, and show that to the water were frequently ascribed impurities which did not belong to its original and proper quality, took me early in the morning to the new road, and applied a match to the tops of water-plugs, and lighted the gas that escaped from them. Instances were stated of people, on going with candles to the taps in houses to draw water, being surprised by a blaze of gas from them.

The operation of the new steam-rollers, whilst it relieves horses, carriages, and ordinary vehicles from the labor of crushing and forcing down granite, and is in other respects economical for the macadam roads, is productive of injury and waste by a yet more powerful vibrating action than the ordinary traffic, and by a greater disturbance and rupture of the system of pipes beneath the surface. Some of these rollers weigh as much as 30 tons each. I am informed that the gas and water companies in London and in the provincial cities have had serious cause to complain of the use of these rollers, which bring to bear the weight of some 20 or 30 one-horse loads upon one fulcrum, and have fractured large pipes deeply laid, and have also injured the house connections.

In proposing the system of combined back drainage, that is, of carrying water-pipes as well as drains and branch sewers at the backs of lines of houses, instead of in the streets along the fronts, I calculated that, besides saving the expense and inconvenience of carrying drains and pipes under the lower floors of houses, the measure would reduce the evil of the loosening and breaking of house service-pipes, as well as the mains, by removing a large proportion of them from the direct action of the heavy traffic over the granite pavements in the streets.

There can, I think, be no doubt that the indirect economies will be greater than the direct economies from the new principle of covering the streets with even and yet hard surfaces.* One indirect economy will be the reduction of the weight of the vehicles necessary for the paved roads, and thence a reduction of the wear of the roads.

Amidst these economies are to be regarded the reduction of pain as well as the economy of horse-power. I have received from my esteemed correspondent, Dr. Edward Jervis, of Massachusetts, a paper entitled "Our Dumb Animals," published by a new society started there, on the principle of our Society for the Prevention of Cruelty to Animals. They say: "We want to show the people of this country the abuses to which animals are now subjected, and that those abuses affect not only the well-being of the animals and of the public health, but also the tone of public morals, inasmuch as cruelty to dumb creatures begets cruelty to creatures that are not dumb. Our aim is to educate all, and particularly children, to a higher humanity, and to inspire a reverence for the great Creator of all these wonderful forms of animal life, and a more profound consciousness of our duty in regard to them." In this elevated spirit they advert to the Nicholson pavement as against cobble stones. I have seen no account of the construction of this Nicholson pavement. I am assured, however, that as at Paris, on a close comparison with other long tried means, the Val de Travers pavement is now being actively taken up in New York. But I cite the account as corroborative of the principle of a smooth as compared with a rough pavement, and for the Society's discrimination of the elements of humanity with those of economy involved in the application of the principle by whatsoever means. They state that by the new smooth pavement:

"Streets which once had but little else but light pleasure carriages coursing through them, are now filled from morning to evening with heavily-loaded drays, and carts, and carriages of all kinds. The ex-

* In respect to the interior of the metropolis, Sir Christopher Wren's admirable plan for the rebuilding of the city, which is still good as a study, provided for direct lines and for level street surfaces. He would have prevented Holborn-hill and Ludgate-hill. I got Mr Butler Williams, when principal engineer of the College of Civil Engineers, to ascertain by survey how much had been lost by deviations from Sir Christopher's plan—lost by increased gradients as well as by increased distances; when it was proved that the loss of horse-power, and of time on those two hills alone, would almost pay for the reconstruction of the streets and the restoration of the plan of the architect of St. Paul's.

planation is that the teamsters and cabmen have found out that they can drag their heavy loads over the smooth Nicholson pavement with half the wear and tear of team and cart that is expended on the cobble-stone pavement; and so, very naturally and reasonably select those streets which have the smoothest wheel-ways.

"And why should they not? The life of a first-class coach in Boston streets, for example, is diminishing nearly 50 per cent. by the rough cobble over which it is banged from day to day. And the life of all sorts of carriages, carts, and wagons is probably diminished proportionately. The wear of horses, too, is, no doubt, somewhat in the same proportion. The sprung knees and unsound hoofs of our city horses are a continual protest against cobble stone. How can a poor horse be expected to do half his appropriate work, or live out half his appointed days, who is rarely allowed a chance to put his foot down flat on the road he is travelling, but must step and pull over a series of round stones, which afford no firm footing, and which jerk and wrench the carriage in every direction, every motion of which is an unnatural and unreasonable and injuring strain on the faithful animal who is tugging along his heavy load?

"A first-class livery coach, which costs the stable-keeper $1,600 or $1,800, will last as such about half-a-dozen years only in Boston streets. It is then sold for about what has been expended on it in repairs during the time it has been in service; and so the coach is in fact sunk and lost in the course of about 5 or 6 years. And it is very much so with every sort of carriage which is used in our city. Not that they wear out equally quick, but that their life, if we may so speak, is proportionally shortened, and so it is, too, with the poor horses.

"Now let those who have the making and paving of our streets bear these facts in mind, and they will see that true economy, as well as comfort, demands that our streets should be made just as smooth as is compatible with durability, and that cobble-stone pavements should be banished as fast as possible from our city limits."

It is confidently anticipated that the improvement of the road surfaces will lead to the improvement of the shoeing of horses.

The Corporation of the City of London have rendered a public service by the trial of the new material in streets of such tremendous traffic as those where they have had it laid down, but they would render the example more complete by having the surface washed, in certain weathers, by the jet. The municipal authorities of the cities where they have command of a constant supply of water at high-pressure who did this would have the most complete sanitary street surface yet known. From some trials I got made at the first consolidated Commission of Sewers, it appeared that the cost of cleansing the roadway of the Strand by the jet daily would not be more than threepence per house per week. One of the methods then brought forward, of a hose with a movable carrier, for cleansing the streets by jet, has been adopted in Paris, with great success, on the asphalt pavement. If a suitable pavement were provided, we estimated that the streets of the whole of the metropolis might be kept as clean as a gentleman's court-yard at a rate of a halfpenny per week per head of the population—a rate that would effect a great economy of clothes, and of washing, and merchandise. I deem the conditions that require sweepers of street crossings to be a mere barbarism, being clear evidence of the excessive dirtiness of the general surface.

For these reasons chiefly I have taken a personal interest in this Val de Travers pavement, as realizing more than we expect in the amendment of town pavement. It were to be wished that the material were more abundant, that it might be obtained cheaper. As it is, however, although there appears to be no economy in the first construction, as compared with granite, there are evidently very large economies in its use—economies in cleanliness and health, in the preservation of clothes and furniture, in goods, in horse-power, and carriages.

The lower districts occupied by the many—the wage-classes—require a special attention and consideration which they have not yet received. In some of these districts, in the manufacturing towns, a missionary visitor may observe in a dirty lane or unpaved alley, the steps of one house nicely cleaned and pipe-clayed. That is a house occupied by new comers, a young married couple, who have been

brought there from the rural districts by the inducement of high wages at the manufactory, and they could get no other house near the work. On repeating his visit some time after, the visitor will find that the distinction of the clean steps, and also of the clean floor, has disappeared. The housewife has given up the contest with the surrounding filth from the muddy, unpaved place, and the children, in their rural home once cleanly, have become almost as dirty as the house-floor. She bewails the fact that the labor of trying to keep them clean is in vain; they will go out to play, and roll themselves in the mud. Then, being always so dirty, she is ashamed to send them to school. To withstand the depressing influence of the damp and the filth of the place drink comes in, and so all are lowered to the surrounding filth, and, with higher wages, they sink into a lower physical and moral condition.

Now, it is to be maintained, as a duty of the local authorities to provide such paving and cleanly surface conditions in the poorer districts, that there will be no mud for the children to roll in, or to make "mud pies" of, if they would. It is for the local authorities, and in their default —the default, commonly, of low landlords—it is for the central authority so far as to make the population clean—as may be done by cleanly surrounding surface pavement. Of course, a special economy is to be consulted for such work, and is available for those districts where there is little quick carriage or horse traffic, and where the same peculiarly hard road-surface is, therefore, not needed. It is to be hoped that a smooth, non-absorbent, and washable surface may be got at cheap rates by the use of General Scott's "celenite," or some of the concretes, at least for foot-paths and for court-yards. I had intended to propose that these concretes, Portland and others, should be tested. I myself have a fancy for one form of title with a rabetted joint for foot pavements, which I wish to see tried. The cheaper gas-tar asphalts have some merits, but unless they are very well made they soften and smell offensively under summer heats. I am informed of examples in Germany of the use of a good smooth tar concrete for paving of play-grounds of children's institutions. Indeed, I know of one institution in the metropolis where a saving of one-half the shoe-leather was experienced after an improvement of the surface, and the cost of shoes is a very large proportion of the cost of clothing to the working classes. A general economy of shoe-leather to the bulk of the population is to be taken into account as attendant upon an improved surface pavement. The sanitary economy in childhood from the prevention of noxious subsoil emanations, as well as surface emanations from damp, and filth, and dust, will be of itself very considerable.

The economies specified are, however, much frustrated by carrying out the Val de Travers pavement in isolated patches; nor is justice done to the material in respect to cleanliness, while it is subjected to the dirt of side streets and old pavements; nor indeed are the horses fairly dealt with in being suddenly pulled up and made to change their action for short distances. It is obvious that, if the concert of different jurisdictions be impracticable, unity of administration will have to be sought, for the attainment of the benefits available to the public from the improvement.

Unfortunately for the population of the metropolis, and of some others of our cities, the local administration itself is yet retained very much in patches. Even for one line through the metropolis, the action of seven vestries would be needed. In some places we found that streets were divided longitudinally—one longitudinal half being paved and repaired by one parish at one time, and the other half by another parish at another time. The longitudinal halves, too, were cleansed by halves, often by the scavengers sweeping the dirt from one parish into the other. We proposed, to remedy this state of things by a provision that the paving should, go with the drainage jurisdiction, and should comprehend the entire metropolitan area, including the suburbs. It is only on the complete scale of a city and suburbs that the recited economy of horse-power can be achieved. The horse-traction may be reduced by more than one-half on a particular line, but beyond it, and for the unimproved suburbs, the double horse-power will still be needed. As it is, however, the shopkeepers of Cheapside and other streets declare that they are satisfied even with the partial improvement, and better cleansing surface for themselves. It is stated that some

of the vestries amongst whom the main thoroughfares are divided, whilst admitting the demonstrations of impovement which are not to be withstood, state they will wait until their present granite pavements are worn out, or until their contracts for the maintenance and renewals of the objectionable conditions are expired. Meanwhile, by this apparent saving real waste is maintained, excessive filth is being maintained, shop goods being spoiled, discomforts inflicted, and health deteriorated.

With the new available materials, the professors of sanitary science and economical science may put these questions to urban populations :—

Will you obey the command, "Wash and be clean ?"

Will you pave so as to enable you to do so ?

Will you pay for good paving and cleansing, to save the direct expense of filth in clothes and extra costs of washing ?

Will you pay for good paving, to save more than half the expenses of horses and carriages and the costs of transit ?

Will you pay, in good paving and cleansing, to reduce the greater expense of the filth diseases ?

I will only add that, in the investigations to which I have referred, one large sanitary policy was kept in view, that by the measures we proposed for facilitating and cheapening intercommunication, which we were prepared to recommend should be done to the extremities of the suburban relations, the evils of internal overcrowding would be reduced. For the removal of the well-to-do classes to suburban residences extends and cheapens house accommodation to the urban population. If it were possible to drive back the suburban population upon the city, where they have their daily business, or upon the interior of the metropolis, and pile story upon story for their reception, the effect would probably be, in the existing conditions, a double death-rate. In the interests of the interior population, we were prepared to recommend the radiation of public tramways to the extreme of the civic external daily relations. But tramways provide chiefly for one class of society, not for another, the higher class of villa residents, including medical men, to whom it were desirable to provide means of doing with one horse what they must now do with two, as also for much goods traffic and retail distribution. Unfortunately, these economies and any complete civic administrative policy must wait for the advance of superior legislative principles. Time will vindicate them.

The time will come when a local administration will be tested, especially in the lower districts, by the smell of a place and by the look of the people inhabiting it.

LARGE CASTINGS.

From "The Engineer."

Were we to judge solely from the fact that cast iron has but a very limited range in the field of engineering construction, it might be fairly presumed that the difficulty of insuring sound and reliable specimens of this material increases commensurately with the dimensions allotted to them. It will be seen as we proceed with the subject that there is not necessarily any relation between mere size and the other desirable features which should belong to castings of a superior quality. A very great deal depends upon the purpose to which the casting is to be applied. In some instances it may be of a favorable and in others of an unfavorable character. In the case of a bridge the arch form is unquestionably that which is the best adapted for the employment of cast iron, although this material has been extensively employed for horizontal beams. In the early days of railways, horizontal cast-iron girders trussed with wrought-iron rods, were constructed of spans nearly 100 ft. in length ; but the failures which attended this vicious method of bridge building speedily and deservedly brought it to a termination. Although the difficulty of turning out large castings is well known, yet it is not probably this obstacle which has actually prevented cast iron being more extensively employed than it has been. So far as cast-iron arches are concerned, the impediments which are insep-

arable from that particular form, such as the headway requisite, and other conditions dependent upon local contingencies, have virtually imposed a limit to the use of the material. It may be worth while to inquire into one or two of the causes which render the casting of large masses of iron so liable to uncertainty and unsoundness.

Since it is not the actual dimensions, or what is tantamount, the weight of the casting, that puts a limit to the employment of cast iron, the cause of the restricted use of it must be sought for elsewhere. While it is true that the mere weight of a mass of cast iron is no obstacle to its manufacture, yet when a very heavy weight is attended by disadvantages with respect to form and subsequent duty, it exercises a very important influence.

The simplest form in which a casting can present itself is one in which the metal is all in one mass, in which there is no special extension of surface, but the whole material is a solid agglomeration. Such an example is to be found in an anvil block or a cannon ball. In a word, the difficulty of producing in the foundry a sound casting depends upon the ratio between its superficial area and its solid contents. It is, of course, understood that a minimum weight obtains in all cases, and this brings us to another consideration, which in reality is the bar to the manufacture of all very large castings in which the solid contents are small compared with the superficial dimensions. The question turns upon the possibility of producing the casting at one running from the cupola, or any number of simultaneous runnings. Obviously, it is of no consequence to allow an interval of half an hour, or even an hour, to elapse between the consecutive running of the metal in a large anvil block which will take many days before it becomes cool. The successive runnings incorporate easily with one another, because the mass long remains fluid, each running bringing with it an accession of temperature. Moreover, to go a little further, the duty that a casting of this description has to fulfil, is one which calls into play only its weight and *vis inertiæ*. There is, as compared with its mass, little or no strain brought upon it, and its resistance is of the most passive character. Analogically, it is a pure exhibition of brute strength, and nothing else.

Passing on to a form of casting in which the mass of metal is combined with a scientific distribution of it, we come to the girder, which has been already mentioned as constituting a prominent type of construction in the early days of railways. The theory of the cast-iron girder, and the determination of the strains which affect it under given conditions of loading, are as well known as in the case of its fellow composed of wrought iron; yet, in practice, the sphere of action of the latter is nearly 10 times that of the former. In comparing the two classes of construction, it must not be forgotten that they are both subject to the same character of strains under ordinary conditions; they are subjected to strains of compression and tension, those of a compressive nature affecting the upper flanges, and those of a tensile the lower. The limit of the action of these strains is accurately defined by the neutral line, or, as it is frequently called, the neutral axis of the beam. But while the two descriptions of structure are equally affected, their separate resisting powers are very different. Wrought iron has a ratio of compressive to tensile resistance of about 4 to 5, while that of cast iron is as 7 to 1, nearly. In small examples the upper and lower flanges of a wrought-iron girder are usually made equal in sectional area, as there is nothing gained in attempting to adhere too closely to theory. The flanges of the cast-iron girder, on the contrary, are widely dissimilar in area, the lower being about 7 times that of the upper. Manifestly, when a large cast-iron girder of the form known as the Hodgkinson girder is manufactured, the rate of cooling of the 2 flanges and the web must be very different, and care must be taken to provide for any contingency that might possibly result in consequence. An inequality in the rate of cooling signifies an inequality in the rate of contraction, and it is probable that in many instances a girder or other example of the cast-iron type of construction may, from this cause, be subjected to an initial strain which is never anticipated. In addition to this danger, there are numerous others to be guarded against, such as air-holes, bubbles, cracks, and various defects, the nature of which has been admirably explained by Mallet, and there-

fore requires no special consideration at our hands.

Of the different specimens of castings, cylinders for bridge piers and columns are undoubtedly those which are the most favorably situated so far as the material itself is concerned. If properly and truly bedded, they are acted upon by no other force than that of a direct vertical pressure. It might be inferred from this that it would be easy to cast them of very large dimensions, but a little reflection will point out that they are, from what has been already stated, by no means well suited for being manufactured in single castings. The proportions between the solid contents and the superficial dimensions of a cast-iron cylinder of 10 ft. or 12 ft. in diameter, and 1 in. or 1¼ in. in thickness, is just the very reverse of what it should be to constitute the running of a large casting in that form an easy matter. The danger of successive runnings is that in the interval which must elapse between the meltings in the cupola, the metal already run into the mould has partially cooled, and perhaps solidified also to some extent. Instead, therefore, of the whole casting being one homogeneous mass, it may be split up, as it were, into as many distinct sections as there were successive meltings in the cupola. It is quite possible that there might be absolutely no cohesion or agglomeration of the metal at the places where the different supplies were poured in; in fact, the cylinder might have a number of "straight joints" all round it, supposing it to consist of a single ring. It is evidently unsafe to cast any single portion of a cylinder of such a size as will necessitate intervals of cooling during the process of running the metal into the mould. The contents of different cupolas or air furnaces, must be made available for one and the same casting, and the operation must be continuous.

There is no question but that engineers are beginning to recognize that large span bridges, gigantic roofs, and enormously heavy castings, are very bad economy, and should be resorted to only when there are no other means of accomplishing the desired object. Mere size is not and never was the highest criterion of engineering ability on the part of the designer, and the history of the Great Western Railway is a lamentable instance of the practical ill-success of the adoption of such a standard. It is always preferable to avoid taxing the resources of the foundry and the workshops beyond their legitimate means. When no other method of affecting an object is available, an ingenious *tour de force* is very commendable, and a judicious departure from the beaten track completely justifiable; but when the necessity does not exist, there is no excuse for incurring the risk, and should accidents occur there is the less excuse for them.

NEW EARTHWORK TABLES.

By W. B. ROSS, C. E.

The number of works and articles which have appeared recently on the subject of earthwork computation may be taken as evidence of the general desire for something less tedious than the methods hitherto employed. The tables here described are simple and universal in their application, being in the main merely a contraction of the usual calculation.

These tables are intended to give the quantity of material in railroad cuttings and embankments from the usual data in an engineer's field book, which are—

1. The centre cut or fill, or the distance of the grade above or below the ground at the centre stake.

2. The horizontal distance of the left side stake from the centre stake.

3. The horizontal distance of the right side stake from the centre stake.

Sometimes the heights of the side stakes above or below grade are given, and when the ground is broken the distances out and heights of one or more additional points are also noted.

By use of the tables the calculation of the number of cubic yards contained between two sections 100 ft. apart is much shortened, when, as is usually the case, the sections are regular, that is, when the surface of the ground from the centre to each side stake can be considered a straight line. There is only one method of calculating the cubic contents of a prismoid, or figure with two parallel faces connected by straight lines, and that is by the prismoi-

dal rule. The divisions or sections of railroad cuttings and embankments are always considered prismoids, and their contents can only be obtained by using the rule:

"Add together the areas of the two parallel sections and four times the area of the section half way between them and parallel to both; multiply by the perpendicular distance between the end sections and divide by six."

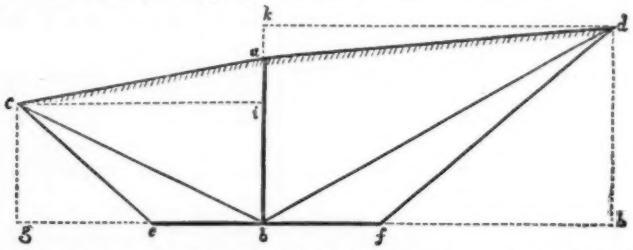
There is a great deal of labor in applying this rule to the calculation of quantities in excavations and embankments, for the area of each of the end sections must be found by dividing it into triangles, for which purpose, and as a record of the work, it is usually drawn upon paper.

The middle section is found by adding together the corresponding lines of the end sections, 2 and 2, and dividing each sum by 2 for the corresponding sides of the new section, and its area is found in the same manner as in the other sections. The distance between the end sections is usually 100 ft., which simplifies the multiplications; but as contractors are accustomed to bid for work in cubic yards, it is necessary to reduce the contents in cubic feet to cubic yards, which imposes the additional labor of dividing by 27.

In the tables this tedious process is much shortened, in the case of regular sections, by performing as many of the operations as possible at once and by use of the tabular form.

HOW THE TABLES ARE MADE.

The simplest way to calculate the area of the regular section a, d, f, e, c, is by dividing it into four triangles by means of the lines bc and bd. Then the area of the section is equal to the sum of the



areas of the triangles abc, abd, bec, and bdf. These areas are

1st. $a\,b\,c = \frac{1}{2}\,a\,b \times c\,i.$
2d. $a\,b\,d = \frac{1}{2}\,a\,b \times k\,d.$
3d. $b\,e\,c = \frac{1}{2}\,e\,b \times c\,g.$
4th. $b\,d\,f = \frac{1}{2}\,b\,f \times d\,h.$

The sum of the areas of the first two triangles $= \frac{1}{2}\,a\,b\,(c\,i + k\,d)$, equal to $\frac{1}{2}\,a\,b \times g\,h$, since $c\,i + k\,d = g\,h$.

In the last two triangles, $c\,g = r \times g\,e$ and $d\,h = r \times f\,h$, r being the ratio of the slope, that is, 1, $\frac{2}{3}$, or $\frac{1}{2}$; where the slope is 1 to 1, $1\frac{1}{2}$ to 1, or 2 to 1, then the sum of their areas is, since $e\,b = b\,f$,

$$= \tfrac{1}{2}\,e\,b\,(c\,g + d\,h)$$
$$= \tfrac{1}{2}\,e\,b\,(r \times g\,e + r \times f\,h)$$
$$= \tfrac{1}{2}\,r \times e\,b \times (g\,e + f\,h)$$
$$= \frac{r \times e\,b \times (g\,h - 2\,e\,b)}{2}$$

since $g\,e + f\,h = g\,h - 2\,e\,b$.

Now, the area of the section consists of two parts, the sum of areas of the first two triangles

$$= a\,b \times \frac{g\,h}{2}$$

and of the second two triangles

$$= \frac{r \times e\,b \times (g\,h - 2\,e\,b)}{2}.$$

Suppose we make a table for computing areas consisting of two numbers for each value of gh or the extreme width of the section; let one be $\frac{gh}{2}$, which multiplied by ab will give the first part of the area and the other be the second part. The areas of sections could be easily and rapidly found from this table, but our object is beyond areas.

Having found the areas of the end sections and four times that of the middle section, we add them together, divide by 6, multiply by 100 and divide by 27, to find the contents in cubic yards by the prismoidal rule. Now these last two operations could be entirely avoided if each number in the table were multiplied by 100 and divided by 27 instead.

This being done, all that will be necessary to obtain the true quantity of material between two sections, will be to find from the width and end height of each section, the quantity from the table and four times the like quantity for the middle section, add them together and divide by 6.

(SPECIMEN TABLE.) BASE 18. SLOPES 1 TO 1.

Tenths. ☞	0		1		2		3		4	
Feet.	Cen. Cut. Multiplier	Add.	Cen. Cut. Multiplier	Add.	Cen. Cut. Multiplier	Add.	Cen. Cut. Multiplier	Add.	Cen Cut. Multiplier	Add.
18.....	16.67		16.76	.8	16.85	1.7	16.94	2.5	17.03	3.3
19.....	17.59	8.3	17.68	9.2	17.77	10.0	17.86	10.8	17.96	11.7
20.....	18.52	16.7	18.61	17.5	18.70	18.3	18.80	19.2	18.89	20.0
21.....	19.44	25.0	19.53	25.8	19.62	26.7	19.72	27.5	19.81	28.3
22.....	20.37	33.3	20.46	34 2	20.55	35.0	20.65	35.8	20.74	36.7
23.....	21.30	41 7	21.39	42.5	21.48	43.3	21 58	44 2	21.67	45.0
24.....	22.22	50.0	22.31	50.8	22.40	51.7	22.50	52.5	22.59	53.3
25.....	23.15	58.3	23.24	59.2	23.33	60.0	23.43	60.8	23.52	61.7
26.....	24 07	66.7	24.16	67.5	24 25	68 3	24 35	69.2	24.44	70.0
27.....	25.00	75.0	25 09	75 8	25 18	76.7	25.28	77.5	25 37	78.3
28.....	25 92	83 3	26 01	84.2	26.10	85.0	26.20	85.8	26.29	86.7
29.....	26.85	91.7	26.95	92.5	27.04	93.3	27.14	94.2	27 23	95.0
30.....	27.78	100.0	27.87	100.8	27.96	101.7	28.06	102 5	28.15	103.3
31.....	28.70	108.3	28 79	109.2	28.88	110.0	28 98	110 8	29.07	111.7
32.....	29.63	116.7	29.72	117.5	29.81	118.3	29.91	119.2	30.00	120.0
33.....	30.56	125.0	30 65	125 8	30.74	126.7	30 84	127.5	30.93	128 3
34.....	31.48	133 3	31.57	134.2	31.66	135.0	31.76	135.8	31.85	136.7
35.....	32.41	141 7	32.50	142.5	32.59	143.3	32.69	144.2	32.78	145.0
36.....	33.33	150 0	33.42	150.8	33.51	151 7	33.61	152 5	33.70	153.3
37	34.26	158.3	34.35	159.2	34 44	160.0	34.54	160.8	34 63	161.7
38.....	35.19	166.7	35 28	167.5	35 37	168 3	35 46	169.2	35.56	170.0
39.....	36.11	175.0	36.20	175.8	36.29	176.7	36 39	177.5	36.48	178.3
40.....	37 04	183 3	37.13	184.2	37.22	185.0	37 32	185 8	37.41	186 7
41.....	37.96	191.7	38.06	192.5	38.15	193.3	38.25	194.2	38.44	195 0
42.....	38.89	200.0	38.98	200.8	39 07	201.7	39.17	202.5	39 26	203 3
43	39.82	208.3	39.91	209.2	40.00	210.0	40 10	210.8	40 19	211.7
44.....	40.74	216 7	40 83	217.5	40.92	218 3	41.02	219.2	41.11	220 0
45.....	41.67	225.0	41.76	225 8	41.85	226.7	41 95	227.5	42.04	228.3
46.....	42 59	233.3	42.68	234.2	42 77	235.0	42 87	235.8	42.96	236.7
47.....	43.52	241.7	43 61	242.5	43 70	243.3	43 80	244.2	43 89	245.0
48 ...	44.44	250.0	44.53	250.8	44.62	251.7	44.72	252.5	44 81	253.3
49.....	45.37	258.3	45.46	259.2	45.55	260 0	45.65	260.8	45.74	261.7
50.....	46.30	266 7	46.39	267.5	46.48	268.3	46.58	269.2	46.67	270.0

BASE 18. SLOPES 1 TO 1.

5		6		7		8		9		Tenths.
Cen. Cut. multiplier	Add.	Cen. Cut. multiplier	Add.	Cen Cut. multiplier	Add.	Cen. Cut. multiplier	Add.	Cen. Cut. multiplier	Add.	Feet.
17.13	4 2	17.22	5.0	17 31	5.8	17.41	6.7	17 50	7.5	 18
18.05	12.5	18.14	13.3	18.23	14 2	18.33	15.0	18 42	15.8	19
18.98	20 8	19.07	21.7	19.16	22.5	19.26	23.3	19.35	24.2	20
19.90	29.2	19.99	30.0	20.08	30.8	20.18	31.7	20.27	32.5	21
20.83	37.5	20.92	38.3	21.01	39 2	21.11	40.0	21.20	40.8	22
21.76	45 8	21.85	46.7	21.94	47.5	22.04	48.3	22.13	49.2	23
22.68	54.2	22.77	55.0	22.86	55.8	22.96	56.7	23.05	57 5	... .24
23.61	62.5	23.70	63 3	23.79	64.2	23.89	65.0	23.98	65.8	25
24.53	70 8	24.62	71.7	24.71	72.5	24 81	73.3	24.90	74.2	26
25 46	79 2	25.55	80.0	25.64	80.8	25.74	81.7	25.83	82.5	27
26.39	87.5	26.47	88.3	26 56	89.2	26.66	90 0	26.75	90.8	28
27.32	95.8	27.41	96.7	27.50	97.5	27.60	98.3	27.69	99.2	29
28.24	104.2	28.33	105.0	28.42	105.8	28.52	106.7	28.61	107.5	30
29.16	112 5	29.35	113.3	29.34	114.2	29 44	115 0	29 53	115 8	31
30 09	120.8	30.18	121.7	30.27	122.5	30 37	123 3	30 46	124 2	32
31.02	129 2	31 11	130.0	31 20	130.8	31 30	131.7	31.39	132 5	33
31.94	137.5	32.03	138.3	32.12	139 2	32 22	140 0	32.31	140.8	34
32.87	145.8	32.96	146.7	33.07	147.5	33.15	148.3	33.24	149 2	35
33.79	154 2	33.88	155 0	33 97	155.8	34.07	156.7	34 16	157.5	36
34.72	162.5	34 81	163.3	34 90	164.2	35 00	165.0	35.09	165 8	37
35.65	170.8	35.74	171.7	35.83	172 5	35.93	173 3	36.02	174.2	38
36.57	179.2	36.66	180.0	36.75	180.8	36.85	181.7	36 94	182.5	39
37.50	887.5	37.59	188.3	37.68	189.2	37.78	190.0	37.87	190.8	40
38.43	195.8	38.52	196.7	38 61	197.5	38.71	198.3	38.80	199.2	41
39.35	204 2	39.44	205.0	39.53	205 8	39.63	206.7	39.72	207.5	42
40.28	212.5	40.57	213 3	40.46	214 2	40 56	215.0	40 65	215.8	43
41.20	220.8	41.29	221.7	41.38	222.5	41.48	223.3	41.57	224.2	44
42.13	229.2	42.22	230.0	42.31	230.8	42.41	231.7	42.50	232.5	45
43.05	237.5	43.14	238.3	43 23	239.2	43.33	240.0	43 42	240.8	... .46
43 98	245 8	44.07	246 7	44.16	247 5	44.26	248.3	44 35	249.2	47
44.90	254.2	44 99	255 0	45.08	255.8	45.18	256.7	45.27	257.5	48
45.83	262.5	45.92	263.3	46.01	264.2	46.11	265.0	46.20	265.8	49
46.76	270.8	46.85	271.7	46.94	272.5	47.04	273.3	47.13	274.2	50

To find the width of the middle section, add together the widths of the end sections and divide by 2; the centre height is found in the same manner.

For convenience, the quantities in the tables should be still further divided by 2, so that it will only be necessary to divide by 3 instead of by 6, as above.

When *ef*, the base, or *r*, the ratio of the slope, changes, of course it will be necessary to use a new table. The specimen table given on pages 596 and 597 is part of the practical table for the base 18 ft. slopes 1 to 1.

The width of the section or distance between side stakes, is given in feet in the left hand column up and down the page, and the tenths from 0 to 9 across the top.

At the intersection of the feet and tenth columns, the centre height multiplier for a section, so many feet and tenths wide is found, and also a number to be added to the product.

When the number of tenths in the centre height is considered a whole number, three decimals should be pointed off in the product.

TO USE THE TABLES.

As each quantity in the tables is the product of a constant and an area, we can use them either for finding the true quantity by the prismoidal rule, or for the approximation by averaging end areas. In the latter case it will only be necessary to find the quantities for the end sections and add them together.

In practice, averaging areas gives a small average error in railroad work, although in the particular case of the pyramid it amounts to 50 per cent. of the whole volume, and in wedges about one-sixth or seventh. This method always produces too great a quantity, while on the other hand the system often employed of using the middle area alone gives too little, and in the case of the pyramid only three-fourths of the contents of the solid.

Since the tabular quantities are produced from the areas by a constant multiplier, we have the rule:

To find the area of any section, multiply the quantity found from the tables by 54.

EXAMPLE BY THE PRISMOIDAL RULE.

Let the first section be called Station O, and the second station 1; the centre cut of the first = 9.8 ft.; the distance from the centre to the left side stake (L. S.) = 20. 2ft., and to the right stake (R. S.) = 16.3 ft.

In the second section let the cut = 15.6 ft., L. S. = 23.9 ft., and R. S. = 26.5 ft.

Putting these data in the tabular form, leaving room between the sections to write their mean quantities or the corresponding data of the middle section, and supposing the base 18 ft. and the slopes 1 to 1, then from the specimen table we have the calculation as below.

Sta.	Cut.	L. S.	R. S.	Sum of Side Dists.	Quantities.		Total Quantities.
0	9.8	20.2	16.3	36.5	33.79 9.8 27032 30411 331.142	154.2 331.1 485.3	485.3
Middle Section.	12.7	....	....	43.4	40.19 12.7 28133 8038 4019 510.413	211.7 510 4 722.1 4 2888.4	2888.4
1	15.6	23.9	26.5	50.4	46 67 15.6 28002 23335 4667 728.052	270.0 728.1 998.1	998.1 3)4371.8 1457.3

As the tabular form here employed is the one in common use in the Field Book, the whole calculation of quantities is easily introduced into its proper

place in the records of the work. Referring to the example by adding together the total quantities for the end sections, we find the cubic yards by averaging end areas to be 1,483.4, which is 26.1 more than 1,457.3, or between 1½ and 2 per cent. error, and by doubling the quantity for the middle section, we have 1,444.2 or 13.1 yards less than by the prismoidal rule.

ADVANTAGES OF USING THE TABLES.

In gaining the above result, we have referred to tables 3 times, made 3 multiplications by tabular quantities, and 1 by 4; there were also 4 additions and 1 division, making in all 12 processes.

Without the tables, we should have been compelled to multiply the extreme width by the centre cut; the sum of side heights by half the width of roadway; to add together the products and divide by 2, making 2 multiplications, 1 addition, and 1 division; or 4 processes for merely finding the area of each section, or 12 for the 3 sections; besides, it would have been necessary to note the side heights or employ the ratio of the slope in the calculation, making it longer.

To find the 4 side heights, to multiply the middle area by 4, to add, to multiply by 100, to divide by 6, and then by 27, makes 9 processes more than by the tables, or 8, when we unite the last 2 divisions, or divide by their product.

Since, generally, we will have the quantity for the first section from the preceding calculation, or, in other words, the area of each section will be used twice, in practice, the prismoidal quantity will be obtained by 9 processes, and an approximation by averaging areas, will require only 4.

There is less liability to error as the operations are fewer and simpler in this than in other methods, and any assistant can easily be taught to use it and the accuracy of his work readily tested.

THE TEMPERATURE OF THE SUN.

By CAPTAIN JOHN ERICSSON.

From "Nature."

The increase of the volume of atmospheric air, under constant pressure, being directly proportional to the increment of temperature, while the coefficient of expansion is 0.00203 deg. for 1 deg. of Fahrenheit, it will be seen that a temperature of 3,272,000 deg. Fahr. communicated to the terrestrial atmosphere would reduce its density to $\frac{1}{6643}$ of the existing density. Accordingly, if we assume that the height of our atmosphere is only 42 miles, the elevation of temperature mentioned would cause an expansion increasing its height to $6643 \times 42 = 279{,}006$ miles. This calculation, it should be observed, takes no cognizance of the diminution of the earth's attraction at great altitudes, which, if taken into account, would considerably increase the estimated height. Let us now suppose the atmosphere of the sun to be replaced by a medium similar to the terrestrial atmosphere raised to the temperature of 3,272,000 deg., and containing the same quantity of matter as the terrestrial atmosphere for corresponding area. Evidently the attraction of the sun's mass would under these conditions augment the density and weight of the supposed atmosphere nearly in the ratio of 27.9 : 1; hence its height would be reduced to $\frac{279{,}006}{27.9} = 10{,}000$ miles. But if the atmosphere thus increased in density by the sun's superior attraction consisted of a compound gas principally hydrogen, say 1.4 times heavier than pure hydrogen, the height would be $10 \times 10{,}000 = 100{,}000$ miles. The pressure exerted by this supposed atmosphere at the surface of the photosphere would obviously be $14.7 \times 27.9 = 410$ lbs. per sq. in., nearly. Unless, therefore, the depth greatly exceeds 100,000 miles, and unless it can be shown that the mean temperature is less than 3,272,000 deg. Fahr., the important conclusion must be accepted that the solar atmosphere contains so small a quantity of matter, that, notwithstanding the great depth, it will offer only an insignificant resistance to the passage of the solar rays. Now, the assumed mean temperature, 3,272,000 deg., so far from being too high, will be found to be considerably underrated. It will be recollected that the

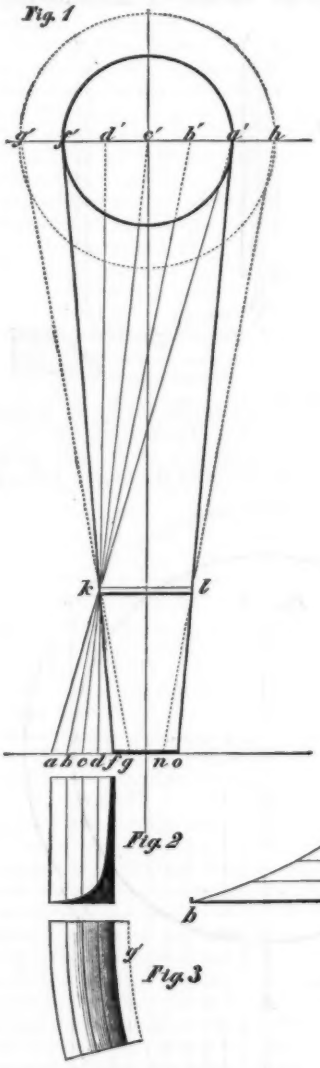
temperature at the surface of the photosphere, determined by the ascertained intensity of solar radiation at the boundary of the earth's atmosphere, somewhat exceeds 4,035,000 deg. Consequently, as the diminution of intensity caused by the dispersion of the rays, will be inversely as the convex areas of the photosphere and the sphere formed by the boundary of the solar envelope, viz., 1.52 : 1, the temperature at the said boundary will be

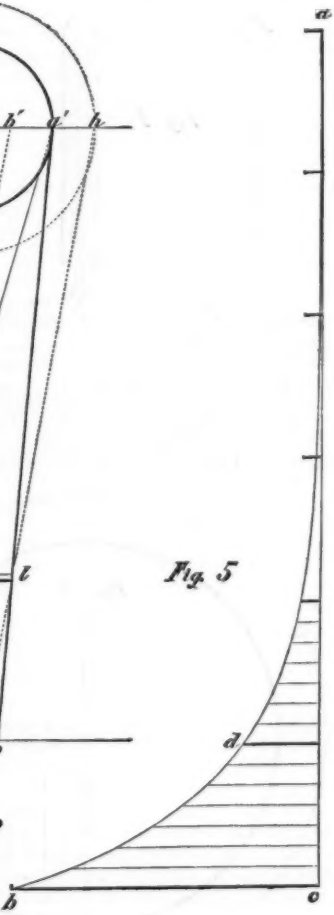
$$\frac{4,035,600}{1.52}=2,654,000 \text{ deg.}$$

The true mean, therefore, will be 3,344,800 deg., instead of 3,272,000 deg. Fahr., a difference which leads irresistibly to the inference that, either the solar atmosphere is more than 100,000 miles in depth, or it contains less matter than the terrestrial atmosphere, for corresponding area. It will be demonstrated hereafter that the retardation of the rays projected from the border of the photosphere consequent on the increased depth of the solar atmosphere (supposed to be the main cause of the observed diminution of energy near the sun's limb), cannot appreciably diminish the intensity of the radiant heat. The ratio of diminution of the density of the gases composing the solar atmosphere at succeeding altitudes, is represented by Fig. 5, in which the length of the ordinates of the curve *a d b* shows the degree of tenuity at definite points above the photosphere. This curve has been constructed agreeably to the theory that the densities at different altitudes, or what amounts to the same, the weight of the masses incumbent at succeeding points, decreases in geometrical progression as the height above the base increases in arithmetical progression. The vertical line *a c* has been divided into 42 equal parts, in order to facilitate comparisons with the terrestrial atmosphere, the relative density of which, at corresponding heights, is obviously as correctly represented by this diagram as that of the solar atmosphere. It is true that, owing to the greater height of the latter compared with the attractive force of the sun's mass, the upper strata of the terrestrial atmosphere will be relatively more powerfully attracted than the upper strata of the vastly deeper solar atmosphere. The ordinates of the curve *a d b* will therefore not represent the density quite correctly in both cases. The discrepancy, however, resulting from the relatively inferior attraction of the sun's mass at the boundary of its atmosphere, will be very nearly neutralized by the increased density towards that boundary, consequent on the great reduction of temperature—fully 1,380,000 deg. Fahr.—caused by the dispersion of the solar rays before entering space. It may be well to add that, in representing the relative height and pressure of the terrestrial atmosphere, *a c* in our diagram indicates 42 miles, while *b c* indicates a pressure of 14.7 lbs. per sq. in.; and that in representing the solar atmosphere, *a c* indicates 100,000 miles, and *b c* 410 lbs. per sq. in. Bearing in mind the high temperature and small specific gravity, the extreme tenuity in the higher regions of the solar atmosphere will be comprehended by mere inspection of our diagram. Already midway towards the assumed boundary, the density of the solar atmosphere is so far reduced that it contains only $\frac{1}{152000}$ of the quantity of matter contained in an equal volume of atmosphere at the surface of the earth.

Let us now consider the diminution of intensity occasioned by the increased depth through which the heat rays pass which are projected from the receding surface of the photosphere. Fig. 6 represents the sun and its atmosphere extending $\frac{1}{4}$ of the semi-diameter of the photosphere, *m h*, *c g*, etc., etc., being the heat rays projected towards the earth. The depth of the solar atmosphere at a distance of $\frac{1}{2}\frac{9}{0}$ of the radius from the centre of the luminary will be seen to be only 2.0012 greater than the vertical depth. Now, careful actinometer observations enable us to demonstrate that when the zenith distance is under 60 deg. the radiant energy of the sun's rays in passing through the terrestrial atmosphere is very nearly in the inverse ratio of the cube root of the depth penetrated (see the previously published table). The increase of depth resulting from atmospheric refraction, it may be well to observe, is too small at moderate zenith distances to call for correction ; nor does the atmospheric density vary sufficiently during bright sunshine to affect the radiant intensity appreciably. The table adverted to shows that an increase of the sun's zenith distance of 5 min. in 60 deg., occasions a diminution of temperature hardly amounting to 0.044 deg. Fahr. Adopting the same

rate of retardation for the solar atmosphere as that observed in the terrestrial atmosphere, it will be found that the loss of radiant energy of the solar rays at $\frac{1}{20}$ of the radius from the border of the photosphere will be only 1.26 greater than at its centre. According to the researches of Secchi and others, the loss is fully three





times greater than that established by the rate of diminution which we have adopted. This circumstance, in connection with the extreme tenuity of the solar atmosphere, rendering any considerable loss improbable, points to the fact that some other agency than increased depth is the true cause of the diminution of the temperature under consideration. Accordingly, the writer some time ago instituted a series

of experiments with incandescent cast-iron spheres, for the purpose of ascertaining practically if the reduction of temperature could be accounted for solely on the ground that the obliquity of the rays diminishes their energy. Previous experiments had demonstrated that the accepted doctrine is quite incorrect, which teaches that heat rays emanating from the surface of incandescent radiators are

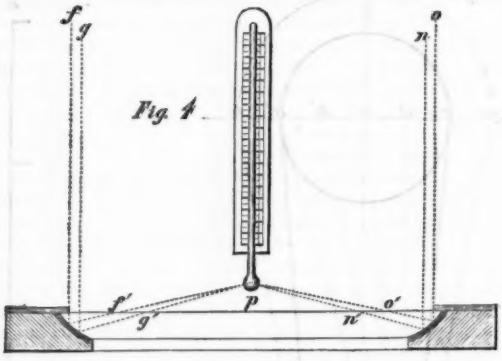


Fig. 4.

projected with equal energy in all directions. It was found during those experiments that the ratio of diminution of radiant heat transmitted to a stationary thermometer by an incandescent circular disc of cast iron, turning on appropriate journals, is directly proportional to the sines of the angles formed by the face of

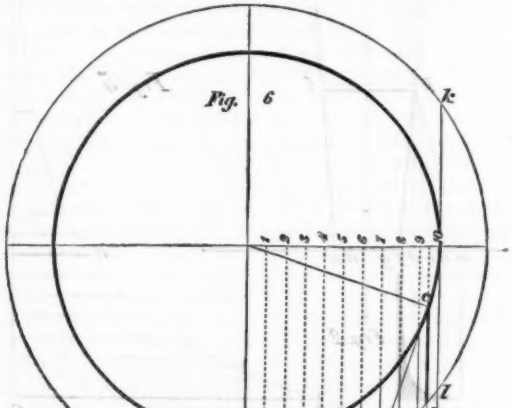


Fig. 6.

$a\,b = 1.0000 \quad c\,d = 2.0012$

the disc and lines drawn to the centre of the bulb of the stationary thermometer. It was clearly shown that those heat rays only which are projected at right angles

to the face of the incandescent radiator, transmit maximum energy. The important bearing of this fact with reference to temperature transmitted by the heat rays of the photosphere from points near the border, is self-evident. The small angle formed by the ray $c\ g$, Fig. 6, and the tangent $c\ f$ of the surface of the photosphere at c, explains satisfactorily why the radiant heat at a distance of $\frac{1}{10}$ of the radius from the sun's border, is considerably less than at the centre. It will be perceived that the angle $f\ c\ d$ diminishes very rapidly as the border of the photosphere is approached, and that when the extreme point is reached, the radiant heat transmitted would be infinitesimal if the irregularity of the surface of the photosphere did not present a series of inclined planes capable of projecting heat rays in a direct line with $k\ l$.

Laplace, in the famous demonstration by which he proves that "if the sun were stripped of its atmosphere, it would appear twelve times as luminous" ("Mecanique Celéste," tom iv., pp. 284—288), commits the grave mistake of assuming that all rays emanating from a radiant surface possess equal energy. This assumption leads him further to the erroneous conclusion that the rays projected from the retreating surface of the sun near the limb, act as rays from a lens, being crowded together in consequence of the obliquity of the radiant surface, thereby, he supposes, acquiring increased intensity; hence the monstrous assertion of the great mathematician, that, but for the interference of the solar atmosphere, the luminosity would be twelve times more intense.

The important question whether the solar atmosphere possesses any appreciable radiant power, and whether the high temperature of the attenuated matter of which it is composed, exercises any marked influence on the sun's radiant energy, may unquestionably be answered practically. An investigation, based on the expedient of concentrating the heat rays of the chromosphere by means of a parabolic reflector, has been conducted by the writer for some time. The method adopted is such that only the heat rays, if such there be, from the chromosphere and exterior solar envelope, are reflected; while the rays from the photosphere are effectually shut out. Fig. 1 shows the general arrangement; $f'\ a'$ represents the photosphere, and $g'\ h$ the boundary of the surrounding atmosphere; $k\ l$ is a circular screen exactly 10 in. in diameter, placed 53.76 in. above the base line $a\ o$. This distance obviously varies considerably with the seasons. Assuming that the investigation takes place when the sun subtends an angle of 32 min. 1 sec., the screen $k\ l$, if placed at the distance mentioned, will throw a shadow, $f\ o$, exactly 9.5 in. diameter; hence objects in the plane $a\ o$ placed within $f\ o$, will be effectually shut out from the rays projected by the photosphere, while they will be fully exposed to the rays, if any, emanating from the chromosphere and outer strata of the solar envelope.

It should be observed that, owing to diffraction in connection with the extreme feebleness of the sun's rays projected from the border, the shadow thrown by the screen $k\ l$ extends considerably beyond the circular area defined by $f\ o$. Fig. 3 exhibits a *full size* segment of this shadow as it appears round $f\ o$, the section colored black in Fig. 2 being a photometric representation of the strength of the said shadow from f to a. Special attention is called to this photometric representation, as it shows that objects placed within the circular area defined by $f\ o$ are absolutely screened from the rays of the photosphere. It is evident that a parabolic reflector of proper size placed immediately below $f\ o$, will concentrate the radiant heat, if any, transmitted by the rays $f'\ f$ and $g'\ g$, and the intermediate rays. Fig. 4 represents a section of the parabolic reflector which has been employed during the investigation. It consists of a solid wrought-iron ring lined with silver on the inside, turned to exact form and highly polished. An annular plate 9.5 in. internal diameter, is secured to the top of the wrought-iron ring to prevent effectually any rays from the photosphere reaching the reflector. The prolongation of the rays $f'f-g'\ g$ and $h\ n-a'\ o$ are shown by dotted lines $f\ g$, and $n\ o$; also the reflected rays directed towards the bulb of the focal thermometer, marked respectively f', o' and g', n'. The investigation not being yet concluded, the following brief account is deemed sufficient at present. Turning the reflector towards the sun, without applying the screen $k\ l$, a narrow zone of dazzling white light is pro-

duced on the black bulb of the focal thermometer, the mercurial column commencing to rise the moment the rays strike the reflecting surface. With a perfectly clear sky, the column, during an experiment on August 29, 1871, reached 320 deg. Fahr. in 35 sec. The screen *k l* being applied after cooling the thermometer, a zone of feeble grey light appeared on the black bulb nearly as wide as the one produced by the rays from the photosphere, but situated somewhat lower. The column of the focal thermometer, however, remained stationary, excepting the oscillation which always takes place when a thermometer is subjected to the influence of the currents of air unavoidable in a place exposed to a powerful sun. It is proper to remark that, owing to the stated oscillation, it cannot be positively asserted that there was no heating whatever produced by the reflection and concentration of the rays which formed the zone of grey light adverted to. But the recorded oscillations prove absolutely that the heating did not *exceed* 0.5 deg. Fahr.

Assuming that such a temperature was actually produced by the reflected concentrated heat emanating from the solar envelope, the following calculation will show that the energy thereby established is too insignificant to exercise any appreciable influence on the sun's radiant power. Theoretically, the temperature transmitted to the bulb of the focal thermometer by the rays *f* and *o*, Fig. 4, is inversely as the foreshortened illuminated area of the reflector to the zone of light produced on the bulb. Obviously these areas bear nearly the same relation to each other as the squares of *f'* or *o'* to the square of the radius of the bulb *p*. The length of *f'* being 4.77 in., while the radius of the bulb is 0.125 in., calculation shows that the temperature transmitted by the ray *f* would be increased 1,456 times if the reflector did not absorb any heat. Allowing that 0.72 of the heat is reflected, the augmentation of intensity by concentration will amount to $0.72 \times 1{,}456 = 1{,}048$ times the temperature transmitted by the rays *f* and *o*. The records of the oscillations of the mercurial column during the experiments show, as stated, that the temperature resulting from concentration cannot exceed 0.5 deg., hence the temperature transmitted by the rays emanating from the heated matter of the solar envelope will only amount to

$$\frac{1}{2 \times 1084} = 0.00047 \text{ deg. Fahr.}$$

The observations having been made when the sun's zenith distance was 32 deg. 15 min., a correction for loss occasioned by retardation amounting to 0.26 will, however, be necessary. This correction being made, it will be found that the heat actually transmitted by the rays from the solar envelope during the experiment of August 29, did not exceed 0.00059 deg. Fahr., a fact which completely disposes of Secchi's remarkable assumption that the high temperature of the photosphere is owing to the "radiation received from all the transparent strata of the solar envelope" (see his letter to "Nature," published June 1, 1871). But we are not discussing the cause; the degree of temperature at the surface of the photosphere is the problem to be solved.

It was stated in the previous article that the radiant power of incandescent metals, and metals coated with lamp-black and maintained at boiling heat, is directly proportional to the temperature of the radiator. A series of experiments with flames just concluded, proves positively that under similar conditions a given area of flame of uniform intensity transmits the same temperature as incandescent cast iron. Secchi's assertion, therefore, that the photosphere, if composed of incandescent gases, "may have a very high temperature and yet radiate but very little," is wholly untenable. The diminution of intensity attending the passage of the heat rays from the photosphere through the surrounding atmosphere, is the only point which can materially affect the question of temperature. We have shown that on a given area, the quantity of matter contained in the solar atmosphere cannot greatly exceed that of the terrestrial atmosphere; hence the retardation cannot be great. True, the depth of the solar envelope is vast compared with that of the earth's atmosphere, but distance *per se* does not affect the propagation of radiant heat. Admitting, however, the retardation to be as the cube root of the depth—the ratio observed in the terrestrial atmosphere—it will be found that the loss of energy produced by retardation of the heat rays is not important. The solar atmosphere being

$$\frac{100{,}000}{42} = 2381$$

times deeper than the earth's atmosphere, the retardation caused by the former will be 13.3 times greater than that of the terrestrial atmosphere, which, as we know, diminishes the radiant intensity 17.64 deg. on the ecliptic. Accordingly we are justified in asserting that 13.3 $\times$ 17.64 deg.= 234.6 deg. Fahr. will be the greatest possible diminution of temperature caused by the retarding influence of the matter composing the solar envelope. The admission in the previous article, that the retardation under consideration might be 0.01, was based on the extreme assumption that the obstruction is directly proportional to the depth of the sun's atmosphere. At first sight, the loss of 234.6 deg. appears to be a trifling reduction of energy; yet if we consider the mechanical equivalent which it represents, we cannot doubt its adequacy to supply the motive force expended in producing the observed movement of the attenuated matter within the solar atmosphere. Dividing the temperature of the photosphere, 4,035,000 deg., by 234.6, it will be found that the computed, apparently insignificant, retardation exceeds $\frac{1}{17,000}$ of the entire dynamic energy developed by the sun—an amount fully 15,500 times greater than the solar energy transmitted to all the planets of our system! Making due allowance for the extreme attenuation, and the small quantity of matter to be moved, the most exaggerated computation of the probable expenditure of mechanical energy called for in keeping up the currents of the solar atmosphere, fails to establish an amount at all equal to that capable of being generated by utilizing 234 deg. of the radiant heat emanating from the photosphere.

In view of the foregoing statements, and the demonstrations contained in the previous article on solar heat, we cannot consistently refuse to accept the conclusion, that the temperature at the surface of the photosphere is very nearly 4,036,000 deg. Fahr.

CRITICAL EXAMINATION OF THE IDEAS OF INERTIA AND GRAVITATION.

By JAMES D. WHELPLEY.

7.—THE LAWS OF FALLING BODIES.

In section No. 1* I have given a series expressing the increase and diminution of motivity in a planet moving in an elliptical orbit, and whose distance from the sun is continually changing. The velocity of such a planet was found by Kepler to vary inversely as the distance from the sun, and I have assumed that the force which unites the planet and the sun varies in the same ratio; the multiplication of the two series giving a third which expresses the ratios of motivity generated in the planet by the solar influence at different distances. Newton made the intensity of gravitation to vary as the square of the distance inversely; giving a series precisely similar in value with that which is obtained in sec. 1, by multiplying the inverse velocities into the inverse intensities of the actuating force. But there are still other series expressing the same mathematical conditions. We may assume that the intensity of gravitation in a planet approaching the sun, varies as the square of the velocity of the planet; which will give the same series, but will not express any physical truth or law; velocity being in no sense a *cause*, but always a result of force. Another series, which not only contains the mathematical but the physical truth, is obtained by squaring the series of numbers that express the intensity of gravitation; *assuming*, always, that gravity varies simply as the distance inverse. The series given in sec. 1, in which the velocity is multiplied into the force, is defective, because it also implies that velocity is a cause, or multiplier.

It will be presently demonstrated, by analysis of the phenomena of falling bodies that the effect of the solar influence in producing motor force, or momentum, is as the square of its intensity; and the series of these squares corresponds with the Newtonian formula of the distance square inverse.

The modern idea of motor force did not exist in the Newtonian system.

A careful analysis of the laws of falling

* See page 496 of this Journal for November, 1871.

bodies will enable a much clearer understanding of all of these points.

A body is said to be "falling," when it is approaching the earth from a short distance under the influence of gravity. Newton first showed the necessity for regarding the action of gravity as mutual between the falling body and the earth; each moving the other with equal force, but with velocities inversely as their masses.*

It is hardly necessary to say that a falling body near the earth moves in an orbit, holding in fact a true planetary relation with the earth.

To simplify the problem, we may regard the trajectory of a falling mass as a straight line passing through the centre of the earth and of the body itself.

Near the level of the sea a body falls at the rate of 16 ft. and a fraction in 1 sec.; a rate too rapid for accurate measurement of the spaces passed over; but in Atwood's machine, a weight is retarded by a counter weight, so that its velocity may be reduced to 1 ft., or less, for the first second of time, the law of acceleration acting through successive seconds as if the weight were free.

Let the weight, then, be falling 1 ft. in the first second of time. This is not a slow movement of falling, since it is known that if the earth were to begin now to fall into the sun, it would move during the first second only a little more than one-tenth of an inch.

In falling 12 in., beginning from rest, or no velocity, the weight acquires a velocity of 2 ft. per sec. It has had then, an *average* velocity of 1 ft. per sec. During the next second, the weight having acquired a velocity of 2 ft. to begin with, is accelerated as much as in the first. At the end of the second second it has therefore acquired a velocity of 4 ft. During the third, beginning with a velocity of 4, it acquires by equal acceleration a speed of 6 ft. per sec. The *average* velocities of the first, second, and third seconds of falling, are 1, 3, and 5 ft. From these averages, John Bourne, in his Treatise on the Steam Engine has deduced the true or natural law of momentum, as follows:

The gravitation of the weight for short distances is assumed to be a constant force, which he calls a "pressure,"† represented by p. By the modern method of calculating motor forces, under the name of foot-pounds, or horse powers, the pressure, or actuating force, is multiplied by the velocity; and this, again, by the duration of the action.

"The power exerted during the first second was as the pressure$\times$velocity$\times$the time$=p\times1\times1$; in the 2d sec. $p\times3\times1$; and in the 3d, $p\times5\times1$; hence the total power exerted, was $p\times(1+3+5)=p\times9$."

From this we see that the power required to bring a body from a state of rest to a velocity of 6 ft. per sec. (end of 3d sec.) "is represented by 9, while the power required to bring the same body from rest to 2 ft. per sec., or *a third* of that velocity is only *one-ninth*." Hence, "to ascertain the power resident in bodies moving at different velocities, we must multiply the pressure by the square of the velocity." Pressure means simply actuating force.

If the weight of the Atwood machine is adjusted to fall 1 ft. in the first second, it will fall 9 ft. in 3 secs. by experiment. Its average velocity, in falling 9 ft., is then 3 ft. per sec. The actuating force, or unit of constant gravitation, multiplied into the velocity multiplied into the time$=p\times v\times t=p\times3\times3=p$ 9, represents the motor force exerted during the 3 seconds;—and we know that this force is not wasted by friction, or expended in "work," but is accumulated in the momentum of the weight. We have here a perfectly simple method of proving that *the dynamic value of a mass moving under a constant force of gravity varies as the square of its velocity.*

Although engineers have long been acquainted with the fact mentioned by Nicholson, that the effect of a blow given by the ram of a pile-driver, is nearly as the distance fallen, or as the square of the average velocity, they have continued to repeat the false and useless formula of the Newtonian physics, that the "quantity of motion or momentum of a moving body is found by multiplying the mass into the velocity."

Indeed, the idea of motor force, as it is understood and employed by the moderns, is not dogmatic or hypothetical, but derived from observation. It belongs exclusively to the present century.

Motion and rest enter jointly into every form of motivity, under the general idea

* The idea of mutual gravitation originated with Kepler. See Maclaurin.

† This expression originated with Newton.

of equipoise; *a disturbance of the equipoise of forces being the exclusive cause of motion, as their equilibrium is of rest.*

The modern idea of motor force (foot-pounds, horse-powers, etc.) includes the idea of resistance, rest or stability, and I have shown by former reasonings that the first effect of all masses upon each other is to impart stability, the element of rest and resistance—the principle of inertia.

The points to be observed in the phenomena of falling bodies are, then, as follows:

1. That the square of the time of falling represents the space fallen through.

2. That the square of the *average* velocity expresses the space fallen through.

3. That one and the same number expresses the space fallen through, and the momentum acquired at the end of the fall.

4. That the average velocity and the time of falling are expressed by the same number.

5. *That either the time of falling squared, or the average velocity squared, or the product of the two, represents the momentum acquired by the fall.*

6. That, with a constant actuating force, the increments of velocity are constant, and the same for every equal fraction of an unit of time.

It remains to consider the effect of an increase or diminution of the actuating force.

If a falling body be actuated from the first by three units of force instead of one unit, it must start with three units of velocity instead of one unit. Under these conditions the weight of the Atwood machine will fall 1 ft. in the first third of a second, 3 ft. in the second, and 5 in the third=9 ft. in 1 sec.

But this also expresses the momentum at the end of the first second; and we have reached the very important and novel conclusion, that, *other things being equal, the distance fallen in a given time, and the momentum at the end of the fall, will be as the square of the actuating force.*

Thus, then, it again appears, as we have already stated (secs. 1 and 7), *that the actuating force of gravitation increases in the simple inverse ratio of the distance;* since a planet falling towards the sun through an infinitesimally small space, will fall with a momentum which is a square of the actuating force, that is to say, the square of the distance inverse of the planet from the sun.

8.—PLANETARY VELOCITIES.

The orbitual velocity of a planet varies, as it approaches and recedes from the sun, as the distance inversely, in a simple ratio (Kepler). The increase of velocity during its approach to perihelion, in the first half of its orbit, is due to the fact of its drawing near to the sun, under the law of acceleration; while the actuating force, or cause of velocity, varies in the same ratio with the velocity, and not as the distance square inverse. The orbitual velocity is augmented, under the laws of falling bodies. The momentum of the planet in its orbit is thus increased during its approach; and *the measure of its increase is found by squaring the intensity of the actuating force.*

When, on the contrary, two planets, for instance the Earth and Jupiter, are separately observed, it is found that the velocities of the two compared together, are in the inverse ratio of the *square roots* of their distances from the sun. Let two planets be distant from the sun, the first four, the second sixteen units of distance, the velocities of the two in their orbits would be as 4 to 2.

"The power that acts on a planet that is nearer the sun is manifestly greater than that which acts on a planet more remote; both because it moves with more velocity, and because it moves in a lesser orbit, which has more curvature, and separates farther from its tangent in arcs of equal length."*

Let two circular orbits of two planets be concentric, the sun being the centre, and the farther planet 4 times as distant as the nearer. The velocities of the two in orbit are known to be as 2 is to 1 (Kepler). Let both move in their orbit through small arcs for a minute of time, the nearer will have moved as far again in the minute, and will have fallen on the curve of the lesser orbit, away from the straight line or tangent, 16 times as far as the other, as may be seen by inspecting a diagram of the movement. But the distances fallen through in equal times by falling bodies, such as the planets falling toward the sun, measure the force which

* Maclaurin, p. 267. The explanation is condensed from his.

causes the fall. The force exerted by the sun upon the nearer planet is consequently 16 times greater than upon the other in equal times; the force exerted by the sun being thus found to be always in the ratio of the inverse square of the distance. Upon the above argument Newton founded his entire system, always assuming that orbitual motion is determined by the "continual falling" of the sun and planets toward one another (in the mean orbit), whereas they do not fall at all, but are mutually at rest, maintaining a constant mean distance. But even if this hypothetical "falling" of bodies that do not fall were admissible, the inference drawn by Newton is incorrect; for I have shown in the analysis of the laws of falling bodies (sec. 7), that the distances fallen in equal times by different bodies will vary *as the squares of the intensities of the actuating forces.* By which it appears that the actuating forces of gravity vary inversely as distance, and not inversely as distance square.

Some very useful deductions may be made from the observation of planetary velocities. We have seen, that when the planets are moving in elliptical orbits, they are vibrating to and from the sun—under the law of "falling" bodies—one vibration being completed during each solar period.

Because of this change of distance, and consequent change of dynamic relation, we find the actuating or radial force evolving motor forces, in the ratio of the square of its own intensity, during such time as the planet is approaching the sun; and the reverse during its recession.

If, then, a system of planets are revolving in relation with the sun, in circular orbits, *the sun and each one of the system of planets are at rest—in regard to each other;* and because they *are* at rest, the gravitating force evolved between them is, in the radial direction, only inversely as their solar distances. But if the length of the *radius vector* shall vary in the smallest degree—changing the distance between the planet and the sun—the *radial force evolved in the mass* at different distances from the sun, will not be in this simple ratio, but "*as the square of the intensity of the actuating force,*" that is to say, *inversely as the squares of the distances.*

It seems hardly necessary to urge so simple an idea, as that the planet and the sun, when at rest in regard to each other, evolve motor forces only in the direction of the orbitual motion.

9.—NATURAL CAUSE OF ORBITUAL MOTION.

To reverse the motion of a moving mass and send it back upon its course in the opposite direction, a force of opposition is required (as in the case of the rebound of an elastic ball), just equal to the momentum of the mass. The direction of the earth's motion in the heavens is exactly reversed in passing from aphelion to perihelion; and a second reversal is effected in the next semi-period; so that *we find the sun's work, in foot-pounds, done in guiding the earth in its orbit from the first of the year to the end of it, is just equal to twice the mean momentum of the earth.*

The original or proper momentum of the terrestrial mass, such as it would be without the guiding action of the sun, is fully taken up in the first half of the year, and again in the second half; so that, in result, *the terrestrial momentum is always a sum of solar effects.*

Because there is no variation of distance between the sun and a planet moving in a circular orbit (mean orbit), there can be no development of motor force in the direction of the *radius vector. But it is certain, that a force is developed,* and it appears in the form we have described. *A guiding or directive force* is mutually evolved in the earth and in the sun, by their fundamental relation. We have seen that this force operates as a constant pressure, and its result in foot-pounds during one annual period is equal to twice the product of the earth's mass into the square of its velocity.

It has been calculated by astronomers that the effect of solar gravitation upon the mass of the earth amounts to $\frac{1}{1600}$ of the proper or self-gravity of the mass upon itself. A mass weighing 1,600 lbs. at the earth's surface is affected by the sun with a force of only 1 lb. But this force, generated by solar relation, and wholly independent of the *proper* inertia of the earth, due to its action upon itself, is "*floated*" on the earth's orbit, and takes the form of inertia.

Hitherto all philosophers have agreed to regard the orbitual curve as produced either by a constant "drag" or a constant "push" of the gravitating force, against the tangent impetus; but it will be much better to look for a probable cause of

orbitual motion, derived from known conditions. We know, for example, that the action of solar gravity is greater on the bright than on the dark side of the earth, because the bright side is 7,912 miles nearer the sun. If, then, the actuating force is inversely as the distance, the difference between the two sides will be as 91,007,912 is to 91,000,000. But the velocities of the two sides of the earth differ directly, and not inversely, as the distance; *the remote or dark side having the longer journey to perform in an equal time.*

We have seen that the actuating force does not evolve motivity in *radius;* the distance between the planet and sun being supposed constant. In the direction of the orbit, on the contrary, there is motion; and consequently, *the motor values of the actuating force at the less and greater distance, determined by the diameter of the planet, will be inversely as the squares of the intensities of that force, at these points.* These quantities are so modified by the differing and inverse velocities of the nearer and farther parts, that the momenta of each particle of the planetary mass will be found equal, as long as the orbit is circular. Let P^2 and p^2 represent the greater and less, or nearer and farther, evolutions of force *in the mass.* To find the motivity, these must be multiplied by the squares of the two velocities, V and v, *which are inversely as the intensities of the actuating forces in any given particle of the mass.*

Let V=greater and v=lesser velocity,

$V \times p = v \times P$, or $V^2 \times p^2 = v^2 \times P^2$.

From which it appears, that in all cases of circular orbits the orbitual momentum is the same and equal for every equal particle of the planet; *the variations of velocities due to the curve, correcting the varying intensity of the actuating force, due to the differences of distance.*

If a planet were moving in a straight line, all the particles would move with equal velocity and momentum; and it would be by reason of this equality that the course of the planet was straight. The perturbing influence of the sun and of all other celestial bodies, produces movements of a highly complicated nature; but always governed by the same equation of momenta. The principle of orbitual motion is, that *in all masses or dynamical systems moving freely in space, the momenta about the axis of movement are equal.*. The nature of the curve is determined by the equation of momenta about the axis, compounded of intensities and velocities. The solar and other celestial influences serve only to evolve the forces *in the mass;* the orbit being the sign of equality between them.

These views do not allow us to imagine that the sun or moon, or any other external force, "drags," "pulls," "pushes" or "presses" the planet away from its "natural" orbit—supposed to be the straight line—into a curve of motion, which is a compromise between contending influences. A "straight" line orbit would be determined by the same laws that determined any curve of motion; nor is one more "natural" than another.

If a planet is moving in a straight line or in a circle, we have seen that the momenta are mathematically equalized about the axis of motion *in the mass;* that axis being in the one case a right line and in the other an arc of a circle; the smallest possible deviation from these, would cause in either case a shift of the axis of equality, and this constitutes a "perturbation" and a change of orbit. But the same law applies to curves of the highest complexity, the direction of the motion being in every case determined so as to effect a balance of the forces.

IRON AND STEEL.

From "The Builder."

The hitherto undiscovered causes of results, apparently so inexplicable and contrary in their effects, to what would otherwise be rules by induction to guide us in our anticipation of producing various kinds of iron and steel, which should possess properties in each case varying in degree in proportion to the quantity of the agent inducted, which should in any proportion give, or appear to give, existence to those properties, must necessarily cause reflection in the minds of many readers, and should, therefore, it may be hoped, be productive of at least a few in-

crements of further discovery and elucidation on the subject.

The consideration of these anomalies presents the following hypotheses, and their resulting conclusions, confirmed, partly at least, by known facts and experiments previously made: Concerning the introduction of carbon in differing quantities producing apparently opposite effects, we may be led to speculate not only on the result effected *in toto*, but on the result produced on the atoms of which it is composed, considering these to be between minute cells, separated from each other by what are usually called the fibres of the iron or steel.

The cells, however minute they may be, will have a defined form, which probably will alter, at the least a little, by any change that may by any means be produced; the variations in the temperature of the weather must produce an increased or diminished size, according to its degrees (and although, perhaps, somewhat foreign to the nature of the investigations we intend at present to pursue, we may pause an instant to consider whether, when a bar of iron increases in size with heat, it increases in exactly the ratio in weight), and the fibres would necessarily alter in consequence, and the question occurs, how would they alter? Would they become thinner in proportion to the cells they inclose, or would they continue to have the same proportion to these cells? And, again, what do these cells contain?

As iron contains carbon and oxygen increasing in proportion as we take samples, beginning with the white iron and going through the various kinds, as mottled iron, bright iron, and the gradations of foundry iron, it would seem probable that the cells in these latter kinds are occupied by oxygen and carbon, and that one or both of these conduce to, or, perhaps, entirely cause brittleness, and that the cells in the foundry iron are much larger than those in the malleable iron. This theory will appear likely from the consideration that foundry iron is lighter than forge iron, and the equivalent of (C) =6, (O)=8, and iron (Fe)=28.04, and twice the size of (C); then the difference in weight of (C) and (O) combined in the larger cells of the foundry iron, and of the weight of the iron itself, corroborates the hypothesis that those cells exist, though, in common with atomic bodies, they are quite invisible by the most powerful microscopic observation.

But it may be urged that these could not exist in forge iron, else how could a bar be drawn out to (say) $\frac{1}{1000}$ part of its previous size? Would those cells then be 1,000 times as long as they were before? If so, then the fibres would be only $\frac{1}{1000}$ part in area, and how could they hold together, either to each other or lengthwise?

In answer to this, let us consider that perhaps the most important and remarkable property of forge iron is that it is almost, or quite, impossible to fuse it (and most probably because its atoms have a powerful and adhesive affinity for one another, which is much interrupted by the carbon in the foundry iron), and therefore it is possible that it may be extended 1,000 times, and not part; but if they would not, we may consider the atoms of this malleable and pliable metal to be like marbles filling a box of, say, 3 ft. by 2 ft. by 2 ft., and their surfaces (although only touching at places) to have so powerful an adhesion as only to be moved, but not separated without being torn asunder or cut, and the interstices between them to be nearly filled by additional portions of iron, which should, being pliable (as we must consider our marbles to be) accommodate themselves to the changing form of the respective atoms to which they must be considered to belong; and let us consider that these interstices contain the cells; then it must be evident that if heat and pressure combined would cause these to slip one upon another, the pressure rendering them perhaps a little elongated, or acorn-shaped, and the cells likewise, and therefore reduced in cubic space within; and if the box, in performing this, were previously to have had its ends removed, then the continuance of the pressure would reduce the contents to 12 ft. by 1 ft. by 1 ft.=its previous cubic contents. This theory of atoms and cells and adhesive properties in malleable iron must be admitted to be possible, because chemists admit atoms to exist, and that they cannot tell their form; and cubes, squares, triangular, hexagonal, or lozenge-shaped prisms can be the only atoms that could leave no interstices, and these are improbable, because they would not easily, if at all, move one upon another in laminating;

therefore, as atoms of any other form must leave cells, then they are at least probable, and also because those atoms are held to be impenetrable; and if there were no cells, then there could be no possibility of their containing carbon. Admitting this, we are bound to consider that when sufficiently heated, the atoms of iron admit the passage between them of the atoms of carbon, and the increase in the size of iron when heated will, perhaps, support this idea; but in this we must not suppose that all the atoms part entirely for the time being; they may act alternately, which might account for the sparkling appearance of iron when at a white heat (the iron in which they would entirely part would, perhaps, be the moulten foundry iron). The foregoing hypothesis, if adopted as probable, leads to the supposition that carbon intervenes to some extent between the places of contact and adhesion, besides existing in the cells of iron, and considerably more so in foundry iron than in forge iron; and that hammering the latter, in increasing its specific gravity, forces its atoms closer together, and the carbon more fully into the cells, and more away from between the places of contact and adhesion of the atoms; and in this case the cells cannot previously have been completely occupied with carbon, and we may infer that they will not be fully so after our hammering; and it will be as evident, as universally known, that the hammering improves the tenacity and strength of the iron, because it brings its atoms closer together; and not only will they have a greater support from each other, but a greater number of them must present resistance to any given area of resisting surface.

It may also be the case, that the cells being nearly, if not quite, enclosed by the atoms, allow of little or no possibility of escape for the carbon and oxygen; and that when a considerable tensile strain is exerted on the iron, that the cells, becoming elongated, and therefore less in volume, exert an elastic force to allow the partial escape of one or other, or both, of the gases confined; and that if the gas or gases were not to find a sufficiently short and ready means of partial escape, that its elastic power (if caused by a sufficient strain) would rend asunder the atoms.

In applying a tensile strain to a bar of iron, the difficulty of escape for the gases must be greater the larger the area of the bar, and for the same reason a round or circular form of section would seem to be the least calculated to facilitate such escape, for if the same area were disposed in a slender, star-like form, the means of escape from the centre of section would be shorter and easier. This hypothesis will explain the fact, that a bar of iron which would bear a strain, when 1 in. sq., of 26 tons, would, when drawn out in the form of wire $\frac{1}{32}$ in. in diameter, bear a strain of 40 tons per sq. in.

In endeavoring to discover a hypothesis which may help to elucidate the cause of the effect produced by carbon in the manufacture of steel, we shall observe that of the four kinds of iron which could in any wise be considered as fit to be converted into steel, viz., grey iron, bright iron, mottled iron, and white iron, that only the bright iron and mottled iron will be really worth using, because the grey iron will be light and fibrous, and would take too much carbon; whilst the white iron (which is the closest grained, or not fibrous), although it is the best and most suitable for forge iron, is, nevertheless, not open or fibrous enough to admit—even with the expansion caused by the heat of the furnace—the induction of the carbon necessary that it should receive in order that it should become good steel.

The fact, however, that steel is heavier than forge iron can leave us, perhaps, no more probable inference than that its cells are fuller of carbon than those of the forge iron, and that its bulk is not greatly, if at all, altered; and that a piece of it may perhaps contain exactly the same quantity of carbon that a given piece of foundry iron contains, but that the piece of foundry iron will in consequence be greater in bulk and inversely lighter in weight than the piece of steel; this being an essential difference between cast iron and steel, the superior strength of steel might lead us to consider that the carbon, when admitted in exactly the right proportion, acts upon and causes the atoms to act upon each other with a vastly increased affinity or attraction, and this because the atoms are near or close to each other.

Tempered steel is lighter than soft steel, and it may therefore be considered that some of its carbon must, by caloric effect, have been eliminated; it is also more brittle and harder; and there is, conse-

quently, a striking analogy in this respect between the comparison of soft steel, with tempered steel, and that of forge iron with foundry iron.

If the heat causing the elimination were not suddenly absorbed by its immersion in pure or acidulated water, brine, mercury, oil, or tallow (for a second tempering after the first in water), or metallic compositions, or by being swung rapidly to cool in the air, then the consequent continuance of such eliminations would cause the steel to lose so much carbon that it would then not be much harder than forge iron.

The tempered steel, being lighter by the supposed extraction of a portion of its carbon, suggests the possibility that its vacated space will be occupied by some other element; if so, a different tempering medium may induct a different element, or the same one in a greater or less degree; from this it will appear probable that such element will be lighter than the carbon, and possibly the carbon remaining in the steel rapidly absorbs one of the lighter gases from the medium it is immersed in; hydrogen, from its lightness and large proportion in oxide of hydrogen would suggest that to be the gas.

This element, whatever it may be, will, while existing in steel, perhaps be of a more non-conducting nature than the carbon it has displaced; and as the latter is a powerful conductor of electricity, it would, when insulated in the steel, reduce in the atoms of steel the opposite kind of electricity (one positive and the other negative electricity), and the partial presence or absence of this electrical induction will perhaps sufficiently account for the superior strength of soft steel, and the greater brittleness of the tempered steel. This hypothesis would seem to be confirmed by the known fact, that magnetic ores and hydrated oxides are unsuitable to be manufactured into steel; this would be because they would be calculated to repel the induction of the carbon; being already charged with electricity, the one would repel the same kind of electricity in another element, viz., the carbon, and the hydrated oxide would repel either kind in another element if it should contain the same.

In order that steel should resist impact to the best advantage, it should the most nearly approach the hardest of forge iron, and should therefore contain the least possible quantity of carbon.

That steel shells should prove much more tenacious than iron when striking armor-plate could not perhaps at present be investigated with a greater chance of approaching the truth, than by supposing these to be of the most tenacious untempered steel, and which would probably have an excess of resisting power to compression, an approach to the malleability of white iron but retaining much of that elastic quality which renders steel so invaluable for springs, and so causes the shell to receive the shock somewhat in the manner that powerful springs receive the concussions of a heavy load in a carriage or cart, the heat caused by the concussion against the armor-plate liberating the carbon, and making the steel still less brittle.

The apparent anomaly of a 68-lb. shot shattering an armor-plate tempered in oil, would perhaps suggest the contemplation of the effect of concussion on a spherical body

If a projectile resists as much as it is resisted, then on striking an (to it) impenetrable object at rest, its own momentum only will react on itself, and its form, if spherical, will possibly cause the resistance to distribute itself through the shot in divergent directions, somewhat in the same manner that the weight of a large arch (under erection) is distributed by the struts in divers directions, and the fact of there being nothing but air behind the ball, would allow it a mobility and power of reaction which could not belong to it if it were resting on an anvil, and were to receive a blow (of exactly the same number of pounds' weight with the concussion) from a steam-hammer above it; but here the force would also be distributed as before, and possibly to a considerable extent counteract upon itself in a partly similar manner to the counteraction of forces manifested in striking the edge of a plank with an Indian club, when, if one particular part of its length touch (the edge of the plank), and that at about one-third the length from its large end, then there will be no vibration or shock to the hand; but if any other place in its length should touch the plank there will, and the same principle is also exemplified in a sabre, when bars of lead stood on end may, by a very strong and skilful

swordsman, have lengths cut off them by causing the right part of the sabre to touch the lead.

The armor-plate becoming shattered by the shot would perhaps be explained by the fact of its being steel at all, and still more so by its being tempered in oil, which is calculated to give the greatest hardness (for this reason oil is used for tempering mint stamps), and the quality that invariably accompanies that—viz., brittleness, and the backing on which it was mounted would also affect it; and in this the particular property of the plate as to brittleness or tenacity would make all the difference in the effect of the shot in the event of the plate not being solidly mounted—*i.e.*, if its backing does not touch it in all places alike. Suppose it to be hollow, and the shot to strike it in the centre and opposite such hollow, and suppose the metal to be tough and not brittle; then the only way in which the shot could effectively operate on it would be by driving a hole right through it, and its being hollow would immensely reduce the effect of the concussion; while on the other hand, if this tough but not brittle plate were fixed on a backing the least convex, then the shot could operate on its centre with its full force. And, on the contrary, if the plate were brittle and not tough, then experiment would probably prove that it would more readily break when slightly hollow at its backing.

And by a similar tendency in brittle steel, and to a lesser extent in soft steel, to fracture with concussion, we may perhaps see the reason why steel vent-pieces were more liable to fracture than those made out of tough iron, and they would probably be less likely to fracture than iron, if instead of being screwed into the gun (as I believe they were), they were to be very accurately turned to fit a corresponding hole to receive them, and (as the gun and the steel vent-piece would probably expand in different degrees under the changes of temperature) it would be well to give a slight draught downwards of (say) one in fifty, so that it could always be made to fit accurately, and thus prevent the vibration the screw vent-pieces would have.

To keep it down in its place the vent-piece should be made with a strong head or flange at top, longer than it is wide, and (to use artillerymen's phraseology) in the front and rear of this head should be a projection on the gun as high as the top of the cap, and these projections should continue over the top of the cap (as far as the latter extends beyond the circular part of the vent-piece), and to have strong screws to keep the cap and its vent-piece down.

To put the vent-piece in, it will only be necessary to turn it round a half circle, that its cap shall clear the screw projection as it goes down.

The vent would be continued through the cap, and which would cause no obstruction to the lanyard in firing the friction tube; but the tangent scale and foresight would in muzzle-loaders have to be placed a little higher.

THE NEW MONITOR TURRET SHIPS FOR COAST DEFENCE.

From "The Mechanics' Magazine."

It will be readily admitted that, while our supremacy on the seas must be maintained by an efficient fleet, of sea-going cruisers, comprising armor-clads, swift corvettes, and gunboats, fully capable of successfully encountering the combined navies of any two foreign powers, it is highly desirable we should possess in addition to these another class of vessels, forming what has been aptly termed a second line of defence, in case disaster should overtake our first line, or that strategy should for the time render it of no avail.

A beginning has been made to supply this desideratum by the four iron-clads ordered to be built by contract shortly after the commencement of the late continental war; they may be expected to be added to our navy in the early part of the coming year. They are of the type known as monitor turret-ships, and, although designed mainly for harbor defence, are yet capable of making considerable voyages under favorable circumstances, of which we have had experience in the voyages of the Cerberus to Australia, and of the Abyssinia and Magdala to India, these

monitors being almost precisely similar to those now building.

As these vessels have but 3 ft. 6 in. freeboard, it will be inferred that they can possess but little stability; such is the case, still they may perhaps have a sufficient amount, as they are not intended to carry sails, but we believe some doubt still exists on this point, and that a lightly-built structure will be made flush with the sides up to the height of the breastwork for a length of about 120 feet, which would make the freeboard upwards of 10 feet for that extent (as in the case of the Devastation, in accordance with the recommendation of the Committee on Naval Design). This will have the effect of considerably adding to the safety of the vessel, by increasing the angles of maximum and vanishing stability. Also to guard against excessive rolling, each of these monitors will eventually be provided with no less than three bilge-keels on each side, and it will be seen that these arrangements are highly desirable, by bearing in mind that the angle of vanishing stability for this class is only 39 deg., which is considerably less than that of the ill-fated Captain. As a set off to this fact, we must remember that the Captain was fully masted and rigged as a seagoing ship, while these monitors will carry no sails and only one mast in the centre, merely for the purpose of getting the boats in and out of place.

This sort of vessel will, on ordinary occasions, be hovering about our coasts, and as they must depend solely upon their steaming powers, it is highly requisite they should steer well. Experience having shown that twin screws are conducive to this result, each vessel will be driven by twin screws with engines of 250 nominal horse power, but the indicated power is required to be 6½ times the nominal, propelling the monitor at an estimated speed of 10 knots per hour.

We consider the quantity of coals carried to be an important element in this type of war vessel, and therefore regret that the weight upon ordinary occasions is to be only 120 tons, as by increasing the breadth 1 ft. and the length 5 ft., which would not be a material increase in their moderate dimensions, 100 tons extra of coals might be carried, supposing the remaining part of the increased displacement to be taken up by the additional weight of engines, etc., for driving the ship at the same speed. We are aware that arrangements are made for coal space, so that 300 tons might be carried on an emergency, but this would necessitate sacrificing no inconsiderable portion of the already small amount of freeboard, which would be decidedly objectionable, especially if required to meet an enemy in unfavorable weather.

The dimensions of the monitors are, 225 ft. between the perpendiculars, 45 ft. extreme breadth, 16 ft. 2 in. depth of hold, 15 ft. 6 in. draught of water, tonnage B.O.M. 2,107, and total displacement about 3,300 tons.

In considering their defensive powers, we are struck with the small amount of surface exposed to the enemy's fire, as contrasted with the extent in the old style of wooden hulls towering up deck over deck, and even when the comparison is made with the broadside armor-clads. But this can be still farther reduced in time of action by admitting water into the space between the two bottoms, leaving little more than the breastwork and turrets above water; at the close of the engagement the bottom would readily be emptied by the pumps.

The system of construction employed is that known as the bracket-plate system; it was first used in the Bellerophon by Mr. E. J. Reed, who thus describes the object of this invention: "For saving weight, simplifying workmanship, and to add both to the strength and safety of the ship." One of its characteristic features, the adoption of an inner bottom, has been proved to be of great value in saving ships which have grounded on rocks, and which, but for this inner skin, must have been unavoidably lost. The cases of both the Great Eastern and Agincourt, than which there are no larger vessels afloat, show how highly it is desirable that every vessel should be thus built, so as to possess the additional element of safety in being still seaworthy when the outer skin is broken through.

The armor on the sides, of a depth of 7 ft., is worked in two strakes, the lower being 6 in. and the upper 8 in. thick, the teak backing behind being 11 in. and 9 in. thick respectively, the skin-plating behind this being 1¼ in. thick; these protective layers taper towards the extremities of the ship, thus diminishing the

weights at the extremities, and so decreasing the tendency to pitch and 'scend.

Rising 6 ft. 6 in. above the upper deck, which is level with the top of the armor on the sides, and giving a passage-way on each side of 5 ft. 6 in. wide, is built another structure termed the breastwork, 117 ft. long by 34 ft. wide, plated with armor 8 in. thick, except in the wake of the turrets, where it is 9 in., backed by 11 in. of teak and another inch of iron worked upon the frames. To complete the protection, between the breastwork and sides, the deck is covered with 1½ in. of iron and 8 in. of teak. On top of the breastwork around the turrets the deck is protected by 1½ in. of iron and 3½ in. of teak, so that some provision is made against the plunging fire to which the decks must be very liable from being so little raised above the water.

Each ship has two revolving turrets enclosed within the breastwork; that portion of them which rises above it is covered with 9 in. thickness of armor, 11 in. of teak backing, and another inch of iron worked upon the frames of the turrets behind the backing; but in the vicinity of the ports, which are necessarily sources of weakness in the armor, the plating is increased to 10 in. in thickness; the top of the turrets is covered with 1 in. plates.

We must not omit, in this description of the defensive power, to mention the pilot-house, which towers 17 ft. above the breastwork, and is protected by 9 in. of armor, 8 in. of teak backing, and 1 in. of skin plating in thickness. This tower is of great importance in enabling the officer who has charge of the vessel to direct her movements at any time and under all circumstances.

Nearly 11 ft. above the breastwork is built a light deck, commonly known as the "hurricane," or "flying deck." On it are stowed the boats, chart-house, and upper steering-wheel; it insures safety and comfort to the watch while the ship is steaming ahead in bad weather. Care has been taken to keep the deck as short as possible—in fact, it but just overlaps the turrets at each end—so that, in case of the end supports being shot away, there is no danger of the turrets becoming jammed by the fallen structure.

For purposes of attack, each turret will carry two 18-ton guns, throwing 400lbs. projectiles. These missiles are too heavy to be carried by hand, and, therefore, overhead rails are fitted for transporting them.

The projecting prow with each monitor as fitted for running down an enemy, is considered, by naval architects of the highest repute, to be a most powerful means of attack, and the bow is strongly framed to enable the shock occasioned by running into an opponent to be the better resisted; for this purpose the longitudinal frames are extended to the stem, to which they are firmly attached. A collision bulkhead is fitted at the third transverse frame from the bow, so that in case of leakage in the fore-compartment, the vessel would still be perfectly safe.

Objection has been made to this mode of warfare, on the ground that the vessel attacking would be quite as liable to injury as the one she ran down; the example of the Amazon running down the Osprey being referred to in illustration of the evil effects, as both vessels sank. But in this case the Amazon was simply an ordinary lightly-built wooden craft with a wooden stem, and it cannot be accepted as evidence, to decide either way, when special preparations are made for the purpose of ramming. That this mode of attack is very destructive and could be safely employed, was shown in several instances during the recent civil war in America. But theory also points out that the shock to such a vessel by impact at a speed of, say 7½ miles per hour, not an improbable one, at the time of collision, would be only equal to that caused by being struck with a 400 lb. projectile at a velocity of about 500 ft. per second.

These requirements are so moderate, that we are forcibly impressed with the conclusion that the projecting prow could be safely employed for such an encounter.

Both the turrets and capstan are worked by independent engines, but in case either of these for the turrets should be disabled, the turret could be readily turned by manual labor, as it pivots round a large hollow spindle firmly secured in the centre, and its weight is borne upon conical rollers under the periphery, each roller being connected by an iron rod to a metal-ring casting, which works round the hollow spindle previously referred to. The steering-wheels are also worked by steam, which seems to be an excellent plan, as the deficiency of steer-

ing power, so long severely felt, has been overcome, and provision is also made, if the steam steering gear should break down, to work in the ordinary manner by hand.

As the crew will be berthed below water, and access of air in the usual way is entirely out of the question, it is satisfactory to find that great attention has been paid to the ventilating arrangements, which are of a most elaborate kind.

In short, these vessels appear to be intricate machines containing a multitude of appliances for the numerous purposes that have to be carried on within them; and it is to be hoped that their merits and demerits, their capabilities and deficiencies, will be fully and fairly tested before any risks are incurred with them.

MECHANICAL FALLACIES.

From "Engineering."

There is a fashion in opinions as well as in clothes, and as we find the cast-off garments of the "upper ten" descending we know not how low, so also views long since discarded as untenable by scientific men still linger in the classes beneath them. Garments and ideas are both altered to suit the wearers, so much so, indeed, as not to be recognized at first sight. This has been the case with "perpetual motion," that will-o'-the-wisp which has constantly eluded the grasp of the inventor at the very moment of success, and has in many cases brought down his grey hairs with sorrow to the grave. It is very generally supposed that the belief in perpetual motion, like the belief in witchcraft, has died a natural death; but this is not the case. It is as flourishing as ever, but in a somewhat different form, and the title "improvements in motive power" covers any number of mechanical fallacies. The patent records furnish some instructive information on the subject, and we will take the year 1866 as an example. In that year 64 patents were granted for obtaining motive power, and twenty of these depend for their presumed action upon the simple principle that $2 + 2$ is greater than 4. They are not only self-moving machines, but they supply power to drive others. It is quite unnecessary to mention them all in detail, but we may speak of a few of them. It is the old, old story. One "engineer" has a wheel provided at the extremities of the arms with flexible bags weighted at one end. The bags open and fill with air as they arrive at the bottom, and the air is forced out as the wheel brings the weighted end uppermost. A "mechanician" patents "a combination of levers and rods" fearful to contemplate, "whereby a greater amount of power is rendered available for use and aiding to overcome the resistance." Another inventor speaks of a "power-creating wheel" which consists of a wheel having a tube of vulcanized india-rubber secured on a portion of its outer periphery, the ends being connected with the hollow axle to which the wheel is attached. The other wheel has an elastic tube on the opposite portion of the periphery, so that one tube may always be undergoing compression. By this means a supply of compressed air is obtained, which, says the enthusiastic individual who proposes the plan, "is the power I use for driving or propelling such engine, carriage, or apparatus." One inventor proposes to gain power by means of a weight revolving at a high velocity, whilst another lays down this principle: "Any body being plunged in a liquid is submitted to two opposite forces; first, its own weight, which tends to lower it; secondly, the pressure of the liquid, which tends to raise it with a force equal to the weight of the liquid displaced by the body. The difference between these two forces" is the motive power which the inventor proposes to use. On the principle of "having one's cake and eating it," a weak-minded enthusiast attempts "to produce motive power by the force of steam acting on a reaction and direct action wheel, both, however, at the same time." In other words his machine consists of the toy known as "Hero's steam engine" combined with Branca's engine. Another equally greedy individual utilizes the force of the steam expended on the bottom and top of the cylinder during the up-and-down strokes of the piston.

"Which is effected by causing the steam cylinder to slide in the reverse direction to the piston." What, however, is most amusing, is the self-satisfied air of the motive-power man, when he condescends to argue. We will take, as an instance, the author of a machine, the name of which perhaps indicates to some extent the "cloudy" condition of the inventor's mind, and which is described in the specification as "an engine manufacturing a power," and of which it is stated that it "constitutes that desideratum so thoroughly 'tabooed' in its assumed impracticability of attainment, that scientific bodies have in instances determined to consider no such question"—and quite right too. The inventor then proceeds to develop his theory at length.

Sceptics are disposed of in the following short and easy manner: "To anyone not educated to the point of incapacity for such a consideration, the demonstration given above would appear amply sufficient. But as a rule the difficulties of surmounting an established creed, which has become a part of the being of its professor, are as insuperable as would be the difficulty of making an intelligent Christian out of an intelligent Mahometan."

We will give one more instance of the eccentricity of the inventorial mind. A patent was granted in 1864 (No. 2,811), for "improvements in developing heat, boiling water, and generating steam." It took two geniuses to accomplish the invention, the one a surgeon and the other a "gentleman." They propose to use a boiler surrounded by rubbers, worked in the first instance by an auxiliary engine. The friction of the rubbers against the boiler will, say the inventors, generate sufficient heat to boil the water and get up steam. So far, good. As a philosophical experiment, such an arrangement is by no means an impossibility. "When the power of the steam in the boiler before mentioned," the specification goes on to say, "is sufficiently developed, the machinery connected with it can be set in motion to secure a similar revolution of wheels or motion of blocks, and the fire in the small engine first mentioned may be let out, and the means used to create the primary motive power discontinued!" The surplus power obtained in this manner is to be applied to any purpose which may be desired. It is worthy of remark that the law officer who passed this patent was Sir Roundell Palmer, who, it should be noted, is strongly opposed to the existence of a patent law. It can hardly be said that he passed the present application by inadvertence, inasmuch as he actually ordered the description originally deposited by the inventors to be amended.

We are not just now advocating any change in the law, but we are justified in asking that two public servants, each receiving an annual income of from £5,000 to £6,000, shall do their duty, and that the solemn farce of protecting, year after year, the very same ridiculous "inventions" by an instrument under the Great Seal may be discontinued. It is only fair to say that the recent agitation for patent law reform has, in some degree, goaded the law officers into a feverish activity. In one case which lately came under our notice, an inventor mentioned that the principle on which his machine was founded was that enunciated in "Mariotte's Law," which he subsequently alluded to as "that well-known law." The law officer objected to this, struck it out of the specification, and said, "let us have nothing about 'well-known laws.' Put it in plain English, so that a plain man can understand it."

It is quite obvious to all unprejudiced minds that the legal and political qualifications of a law officer are of little use, when technical questions often of extreme difficulty and importance have to be considered. We trust that the Select Committee on Patent Law when dealing with the very delicate question of previous examination will bear these facts in mind.

THE following recipe for the preservation of milk appeared in "Cosmos:"—To every litre of unskimmed milk previously poured into a well-annealed glass bottle, add 40 centigrammes (about 6 grains) of bicarbonate of soda. Place the bottle (which must be well corked) containing the milk, for about 4 hours in a water bath, heated to 90 deg. Cent. (194 deg. Fahr.) On being taken out, the bottle is varnished over with tar; and in that state the milk contained in it will keep sound and sweet for several weeks.

RAILWAY GAUGES.*

By R. F. FAIRLIE.

From "The Artizan."

I had the honor last year, of reading before this Association a paper upon "The Gauge for the Railways of the Future," in which I pointed out the capacities of narrow gauge lines, and showed how unfavorably our own railway system, as at present worked, contrasts with such lines when properly handled. The great truths I then put forward were too startling to be received without some degree of ridicule and incredulity; and although I announced them in the full conviction that sooner or later they would be fully acknowledged, I was then little prepared for the rapidity with which that acknowledgment has come. The report of the Imperial Russian Commission upon the Festiniog Railway, produced a similar inquiry on the part of the Indian Government. I had once more the satisfaction of attending a Royal Commission, appointed to investigate the question of narrow gauge; and the results obtained on the second occasion were as satisfactory as those on the first. In Russia, at the instance of His Excellency Count Bobrinskoy, His Imperial Majesty the Emperor commanded a line of narrow gauge railway to be at once commenced, and a number of my engines to be constructed, in order that the accuracy of all I had asserted on the subject, and had shown to the Commission upon the Festiniog Railway, might be proved upon a more extended scale; and that the exact value of a narrow gauge system, for national service, might be ascertained by the fullest tests of experience. The Association will, perhaps, pardon a brief digression, while I here place on record, as a matter of history, the eminent services rendered to the cause of narrow gauge extension by the Russian Commission, and also by Mr. Spooner, the engineer and manager of the Festiniog Railway. This little line, of only 1 ft. 11½ in. gauge, was originally constructed for horse traffic; but was worked after a time by small locomotive engines, resembling, in everything but dimensions, those in common use in England. As thus worked, the traffic outgrew the carrying capacity of the line; and powers to construct a second track were actually obtained. At this conjuncture, Mr. Spooner had the sagacity to perceive the advantage that would accrue from the employment of my system of traction, of which he had read, and the determination to carry out his perception to a practical issue. I constructed for him the now well-known "Little Wonder" locomotive, and thus gave him, on his single line, two-and-a-half times the carrying capacity that he had possessed before. The second track was thus rendered unnecessary, and it has never been made. In the application of all novelties there must ever be risks of failure from unforeseen causes, and hence many, even when they recognize a truth, shrink from the responsibility of being the first to carry it into practice. The acceptance of this responsibility by Mr. Spooner, the opportunities that he thus afforded me of proving the working value of my principles, and the facilities for inspection and experiment that he has since courteously allowed, all fairly entitle him to be considered the father, as his tiny railway has certainly been the cradle, of the narrow gauge system of the future. The next step was made by the Russian Commission. It would be difficult for me to do justice to the infinite care and pains with which Count Bobrinskoy, the President of that Commission, investigated every detail before arriving at his conclusion, or to the earnestness with which he afterward pushed this conclusion to its legitimate results. In Russia, as in other countries, there are men whose interests or whose prejudices lead them to cling to existing systems, and the opposition which proceeded from such persons could only have been overcome by the strength of clear convictions, of unsullied integrity, and of indomitable resolution. Count Bobrinskoy was worthily assisted in his novel and important duty by the other members of the Commission, among whom I may name M. B. Saloff, Professor at the Technical School of Engineering, St. Petersburg; M. von Desen, now resident engineer in charge of the works; and M. Schoubersky, in charge of the rolling stock of the Imperial Livny Railway. To these

* From a paper read before the British Association.

gentlemen the entire civilized world owes a deep debt of gratitude. The line which was constructed and equipped in accordance with their report has now for several months been in operation. The results of its working establish all that I claimed for the narrow gauge; and the final official trials that will take place this month will determine the general adoption of the 3 ft. 6 in. gauge in Russia, together with the employment of my locomotives, without which the value of the narrow gauge at once sinks into comparative insignificance. This rapid action is due to the promptness with which His Imperial Majesty of Russia appreciates progress, to his freedom from prejudice, and to the fact that I have never advanced anything which I have not been able to prove. In India, although I believe ground has not yet been broken, a metre gauge has been decreed for general introduction; and the strongest advocates for the retention of the 5 ft. 6 in. gauge have been entirely defeated. In Australia, Tasmania, and New Zealand, narrow gauge railways have been undertaken, and will be built as fast as means that have been straitened and opinions that have been prejudiced will permit. In South America to a great extent, and in North America—I speak of the United States—to a marvellous degree, the reform I have so long, and at last so successfully, advocated, is making way with an astonishing rapidity. Some 2,000 miles of narrow gauge line are under construction; the great Denver and Rio Grande Railway, 850 miles in length, is being built upon the gauge I have made specially my own; and I may mention that this width of 3 ft. was decided upon by the President and principal officers of the Company after considerable investigation of the principles of my system recommended to their consideration by Mr. George Allan, C. E., who at an early period became strongly convinced of its advantages. A great transcontinental railway from the East to the Pacific is being organized, which, it is expected, will also be on the new narrow gauge. California is building similar lines; the Western States and Territories—pastoral, agricultural, and mineral—are building them; Massachusets, already covered with a network of ordinary gauge railways, is legislating for them; and many others of the Eastern States are earnestly considering the advisability of their immediate construction. As little as yourselves could I have last year imagined that all this progress would have been made in less than twelve months. At that time I was discouraged on almost all sides; I was hampered by the weight of prejudice and of opposition of every kind; but knowing I was right—knowing that the work I had in hand was one which would benefit the whole of the civilized world—knowing that, could I once produce conviction, there need be no country, however poor, that could not be traversed by profitable railways, I persevered, and to-day I find that my efforts have been crowned with a great and substantial success. Need I say that I appreciate this victory, counting the past pains as nothing, and being still more anxious to continue advocating the truth? But it is only due to this Association that I should state how much of my success I owe to its influence, and to the weight thus added to my now celebrated paper on "The Gauge for the Railways of the Future." To that paper I attribute a large proportion of the extraordinary activity that I have described. Stamped with the approval of this Association, the paper has circulated in all countries, and has been translated into all European languages, including those which have been naturalized in South America. It has formed the text for innumerable discussions; it is almost daily quoted in the journals of the United States; and it has excited the most lively interest among the railway engineers of that country, where existing management shows results still more discouraging than those which are obtained in England. The British Association, therefore, more than any other public body, has helped forward a vast reform, and gratefully feeling this, I am encouraged to come here again on this occasion. It is not long since, that to doubt established gauge was professional heresy. A type to which an accident had given birth, had come in course of time to be considered perfect; it was a superstition quickened into a religion. By degrees, after scores of thousands of miles of railway had been built, and hundreds of millions of pounds expended, it began to be seen that there was something still to be desired, and that it was ruinous to make railways for the service of remote districts yielding but small traffic, or in countries whose limited means and commerce could

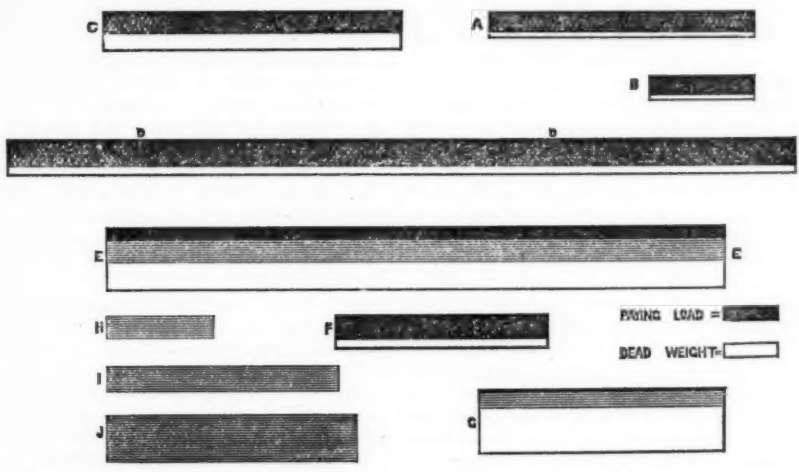
not justify large expenditure. By this time the great outlay which attended the labors of the earliest engineers — the outlay involved by heavy works to gain easy gradients—had been somewhat reduced, and with improved locomotive practice, steeper gradients and sharper curves became possible. Then came the very recent modification of making essentially light lines upon the standard gauge, conforming as much as possible to the natural contour—surface lines, as I was the first to name them in 1864. By adopting them the cost of construction was greatly reduced, and was brought somewhat more into proportion with the revenue to be derived. But these improvements were but improvements upon a bad type, and real reform could not be effected whilst the width of gauge remained, while the rolling stock continued unaltered, and the locomotive rested unmodified. Meanwhile, the history of railway construction in England was slowly repeating itself, even in an exaggerated form, abroad, and particularly in our colonies, where the primitive types were perpetuated by the pupils of the old school of engineers. And here I may remark that the difficulties encountered in this country in railway reform have been faithfully repeated in our colonies—an illustration of cause and effect. Gradually it became known that the ruinous practice of English engineers in Norway had forced the Government of that country to adopt an entirely new type, after the intermediate stage of light standard gauge railways had been largely tested and abandoned, and that for the first time a national narrow gauge system was established. But this was done so quietly, and information filtered so slowly from that isolated country, that until recently only a few have known of the change, and fewer have known, or have cared to inquire, about the practice followed or the results obtained. Of course, exceptional and independent lines of very narrow gauge, established almost universally for mineral traffic, have existed for many years; but these, with the exception of the Festiniog Railway, do not enter into the question; on the contrary, indeed, their small traffic capacities, as worked, have served the opponents of narrow gauge as arguments against innovation. So matters stood when I, having convinced myself of the monstrous errors which cripple our standard railway system, and having learnt the capabilities of narrow gauge—which are yet scarcely understood even by the engineers who are advocating and constructing them—so matters stood when I first devoted myself to the effort of promoting the general introduction of narrow gauge lines, and had the audacity to set myself up in opposition to long-established and deeply-rooted principles. At first, the utmost concession I could obtain—a concession granted but by a few—was that for new countries, where railways did not exist, or for poor countries, where traffic was light and uncertain, a narrow gauge system might be adopted with some amount of advantage; but that its capacity and consequent utility were proportioned to its gauge; and that hence, as a natural consequence, not only must such lines as I recommended be located in districts where only a very small business actually existed, but where also the prospects of its increase were extremely remote. I knew the error of this opinion, for I knew the actual capacity of narrow-gauge railways under proper management; therefore I was encouraged to persevere until, as the circle of conviction widened, I was enabled to put my views to the test of actual and wide experience, and to stir into life the radical reform which to-day is spreading on every side, and which shall before long become general.

I showed you last year how, upon a railway costing one-third less then a line of an ordinary gauge, I could with equal dispatch carry such a traffic as that of the London and North-Western Railway, with a saving of three-fifths of the dead load carried; and how in so doing I could effect a corresponding reduction in engine power, and consequently in cost of fuel, of rolling stock, of engine repairs, and of maintenance of permanent way. All this could be effected at a speed at least equal to the present speed of freight trains for the goods traffic, and at 35 miles an hour for the passenger traffic; a rate which is but little below the average of the mileage made by fast passenger trains in this country. We are so accustomed to the present condition of things—or, perhaps, we are so ignorant of the real elements of railway economy—that it is difficult to believe this great reform possible; but belief was more difficult a year ago than it has since become, now that all my

statements have been proved to be incontrovertibly true. The question, however, is one of such radical importance, that I may once more devote a few words to its elucidation. On the London and North-Western Railway, the average practice is to employ 7 tons of wagon to carry 1 ton of goods, but I assume the proportion of dead weight to be only four to one, in order to make out as favorable a case as possible. The average weight of goods trains on the London and North-Western Railway is 250 tons; composed, in the proportions I have mentioned, of 50 tons of freight to 200 tons of rolling stock. (See diagram E E.) On the Livny (New Russian), (see diagram DD,) 3 ft. 6 in. Railway, on the other hand, the average gross weight of trains is 354 tons, or 104 tons more than that of the London and North-Western, while the dead weight is only 94 tons. This proportion is also shown on the diagram. To carry this paying load of 260 tons on the London and North-Western, 1,040 tons of wagons would be employed, or more than eleven times the weight required by my system. In all my arguments, I of course deal with general goods traffic only, exclusive of minerals. It may be urged against this comparison that the more favorable traffic conditions of the Livny Railway help the results; but it is sufficient to reply, first, that with the reduced gauge reduced weight of wagons in proportion to capacity is feasible; next, that the smaller wagon capacity is essential to economy; and third, that while rolling stock of the smaller class is certain to be loaded more nearly to its ultimate limits, the difference between the maximum load, and the absolute loads obtained in practice, are attended with none of the excessive cost inevitable on a 4 ft. 8½ in. gauge. I would here call your attention to a most important fact in connection with railway goods traffic. The average load of merchandise carried by each wagon in this country is considerably less than 1 ton. Experience has proved that the exigencies of traffic in this country have settled this average, yet wagons of four times this capacity must nevertheless be provided. This fact of itself is sufficient to show that so broad a gauge as the standard one is very excessive. With a narrow gauge this evil may be prevented, and if a higher average per wagon could not be attained, at least a far lower proportion of dead weight would result. This I have endeavored to make apparent in the diagrams, which show the average proportions of dead to paying weight on the 4 ft. 8½ in. gauge, and on the 3 ft. gauge; and I have also placed the load carried as the average by the standard gauge upon a train running on a 3 ft. gauge, the varying proportions being well expressed by contrasted colors. The great economy in working brought about by the causes enumerated above, would react upon railway business, and in increasing it would certainly raise the wagon average, because the cost of carriage would be so much reduced. I think you will agree with me that I am no visionary, but have always spoken within the mark, making my position sure as I advanced, and asserting nothing that I could not prove in actual practice. I have obtained, by the development of my system, results very closely approximating to those I stated last year—namely, three to one of paying to dead load, and I know that this proportion can and will be reached when my views are fully carried out, when a Fairlie gauge is worked with Fairlie locomotives and stock; while by no other system in existence can such results be obtained. In the report of the Royal Railways Commission, published in 1867, the following pregnant conclusions were arrived at from the opinions of the principal engineers and railway managers in this country: "The only way in which an increased receipt in proportion to the cost of running the trains can be anticipated, is in carrying a larger number of passengers in proportion to the number of passenger carriages in the train, and running the goods trucks full instead of partially full; or, in other words, obtaining a greater amount of work out of the engines and carriages than at present. But this means that the passenger trains would be less frequent and more crowded; that the passengers going on to branch lines would have to change carriages more frequently; and that goods would have to be retained until full truck-loads were made up, which would result in a slower delivery of goods." So that, as the necessities of traffic enforce frequent passenger trains, three or four times the necessary weight of carriages must be provided, and as goods cannot be detained until trucks are

fully loaded, it follows that universal extravagance is inseparable from the present system. Railway managers, who are, of course, thoroughly conversant with the subject, agree that our existing railways are at present being worked to the best advantage. If so, it cannot be doubted that there is a grave blunder somewhere; and if this blunder is not to be discovered in management we must seek for it in construction, and there we shall find it. We shall find that railways of the existing gauge will labor under disadvantage for all time; they will remain oppressed by the curse of dead weight, an evil from which they can by no means be relieved; dead weight in their rolling stock for passengers, one ton of which requires thirty tons to convey it; dead weight in their rolling stock for freight, which can never be more than one quarter fully loaded, and dead weight in their locomotives, ill applied for obtaining useful results, but always destructive to the permanent way. Nor does increase of traffic upon a great standard-railway system tend to reduce this evil; if it did, the London and North-Western Railway would not at the present time be expending enormous sums in doubling their permanent way. Experience shows that increased traffic does not diminish averages of weight; for the fact that these averages were larger 20 years ago than they are at present, although the traffic had not then reached half its present dimensions, was simply because the wagons then averaged about a ton less in weight. With a double business, each wagon does carry twice the average amount that it carried 20 years ago; but twice the number of wagons then employed carry each their usual complement of a single ton. There is, therefore, no escape from the conclusion that the existing proportion of dead weight to paying weight upon a 4 ft. 8½ in. railway cannot be reduced, so long as the condition of things exists which guided the Railway Commission to its conclusions, but that it must remain a fixed quantity independent of increase of business on the line. I think no more striking illustration of the error of our present system can be conceived than is afforded by the daily practice of a magnificent company like the London and North-Western Railway; who, at the present moment, be it remembered, have commenced to double the width of their road through press of business; yet who are sending out daily, and daily receiving, at Euston square, some 4,400 passengers, in carriages which contain sitting accommodation for 13,500; and who carry their enormous freight in increments, averaging less than 1 ton, in wagons having six times their capacity. Imagine the amount of capital sunk before this result was obtained! Conceive the waste of engine power, the wear and tear of rolling stock, the destruction of permanent way, the cost of staff, all entailed by this curse of dead weight; and then imagine how easily all this unmechanical and unbusiness-like state of affairs might have been prevented by the simple adoption of a suitable rolling stock running on a suitable gauge! I am not for a moment advocating any radical change in our English railway system; that system has outgrown the season of radical reform, and we must make the best of it as it is; but I seek to prevent the repetition elsewhere of mistakes that have been so costly here. I want to prevent the unnecessary extension of a system that is palpably false, but which is not on that account the less strongly defended and protected. That our great error was known some years since to all thinking engineers, is shown by the quotation I just now made; Mr. G. P. Bidder stated before the Royal Commission: "That great economy may yet be obtained in the transport of minerals over long distances by means of railways laid out under conditions admitting of very long trains being run." In this statement I find the very essence of the question at issue between myself and all conservative engineers; I find the necessity of reform acknowledged, and the means of attaining it hinted at by my warmest opponent. Except that his views did not extend to passengers and goods, but were confined simply to the transport of mineral traffic, we have a complete statement of the problem which I have brought successfully to a solution. The requirements which Mr. Bidder hinted at generally, I have worked out in detail, and have extensively reduced to practice, with results that show his judgment to have been sound so far as it went. The conditions under which a railway should be laid out to meet these requirements, are clearly not those which

rule the present system; ample experience proves the contrary, showing that no line, however full of business, can be worked to its full capacity. We are led, then, unmistakably, to a narrow gauge, to the adoption of passenger carriages which shall be filled, or wagons which shall be almost fully loaded, and of weight which shall bear a reasonable proportion to their capacity, and we are led to the adoption of very long trains and powerful engines. Considering the date of Mr. Bidder's opinions, they could not have been put more clearly or more concisely. To a certain extent, but in a very limited and imperfect degree, experiments were made in the direction indicated—faint foreshadowings of the practice now being so widely introduced—by an attempt to convey extremely heavy trains by means of an auxiliary pair of cylinders placed under the tender of the engine, and receiving steam from the boiler; the idea being, to utilize all the available weight of engine and tender for adhesion. In running expenses, the results of these trials were very satisfactory, showing a large reduction of cost in carrying the heavier load. There were many reasons why this arrangement should prove unsatisfactory, but I quote the results obtained, because they will not be called in question, and because if so much economy could be obtained by such a contrivance as the steam



[The foregoing diagrams represent various proportions between dead weight and paying load, on railway rolling stock, as follows]:

A shows the average load carried in daily practice by the Fairlie engine "Little Wonder" over the Festiniog Railway, 1 ft. 11½ in gauge, the average up grade being 1 in 92. The engine weighs 19¼ tons, the weight of load is over 107 tons, and the proportion of paying to non-paying load is 3 to 1.

B shows the average daily working of the ordinary engine, weighing 10 tons. The load carried is a little in excess of 43 tons.

[The above diagrams show very clearly the capacities of the Festiniog Railway after and before the adoption of the Fairlie engines on it.]

C shows the maximum load of 120 tons carried by the most powerful engines on the 3 ft. 6 in. Norwegian Railway up gradients of 1 in 90. The proportion of paying to dead weight is 1.6 to 1.

D represents the daily working of the freight train of The Imperial (Russian) Livny Railway, 3 ft. 6 in. gauge, up gradients of 1 in 80. The gross load conveyed (exclusive of engine) is 354 tons, of which 260 tons are paying weight. The engine weighs 42 tons, and the proportion of paying and non-paying loads is 2.78 to 1.

E represents the actual ratio between dead and paying loads conveyed in a 250-ton goods train on the 4 ft. 8½ in. gauge; the lighter tint indicating the maximum capacity of the stock, giving 1.8 to 1 of paying to dead weight.

F shows the weight of a train on the 3 ft. gauge carrying the same paying load, 50 tons, as that conveyed by the wagons on the 4 ft. 8½ in. gauge, as shown in the previous diagram.

G is a diagram showing the existing ratio, between dead and paying weight, on passengers train, 4 ft. 8½ in. gauge, as well as its maximum capacity, being 30 to 1 and 2.3 to 1 respectively.

J, H, I, are diagrams showing the comparative dead weights of trains on the 4 ft. 8½ in , 3 ft. 6 in., and 3 ft. gauges respectively, employed to carry 50 tons of paying load, every wagon of each train being loaded up to the present average weight of 1 ton per wagon.]

tender, I may at least claim proportionately advantageous results for the system of which this was an indication. Thus, with an ordinary engine, the cost of conveying a load of 210 tons was 20d. per mile, whilst the cost of conveying a load of 310 tons by the aid of the steam tender was only 23d. per mile. It is obvious that no such saving as this could have been effected had two independent engines been employed upon the same duty. The results clearly prove that a large saving can be effected by increased engine-power and greater loads; but, as I have already pointed out, this economy cannot be realized on railways of the standard gauge; but on the many thousand miles of narrow-gauge railways that will before many years be constructed, the true system of economical working, developed by me, will not only be possible, but will be universally acknowledged and adopted. It would seem a very simple and self-evident fact, that the means of conveyance should be fairly proportioned to the amount to be conveyed, and yet I have been laboring for years to make people understand this. One would think it would be sufficient to point out, to countries contemplating the construction or the great extension of railways, and looking to England and English practice as a model, that the best labors of our engineers, after thirty years' experience, have given us a railway system on which it is necessary to have 4 tons of wagon for every ton of goods, and from 10 to 30 tons of carriages (see the diagram G) for every ton of passengers. And, indeed, abroad it is pretty widely understood, that it can only be on a narrow-gauge railway that a full measure of usefulness can be obtained, and a proper proportion between paying and non-paying load can be secured;—this is because, the amount of engine power being unlimited, better paying trains can be carried on the narrow than on the broad gauge; the difference arising from the fact that the dead weight required for the transport of passengers and goods is reduced in the manner shown by practice and indicated in the diagram. The reform in effected by the adoption of a suitable rolling stock, in which dead weight is kept down by the smallness of the gange, but in which ample capacity is obtained. Such carriages and wagons exactly meet the difficulty which is one of the great causes of dead weight on a 4 ft. 8½ in. gauge—namely, the necessity of transmitting passengers and goods, whenever practicable, to their destination without change of vehicles. With the small carriages and wagons, the expense attending this proceeding is reduced to the lowest possible cost, because, though vehicles of appropriate capacity can be employed, and each can be loaded almost to its full complement of passengers or goods, carriages half or two-thirds empty would never form necessary accompaniments to a train; and even if it were not possible in practice to place a larger share of the load in each vehicle than the present average we should have wagons of 5 tons capacity weighing 1½ tons, instead of others weighing 4 tons to carry the 1 ton average. This capability of subdivision of traffic is one of the most important advantages which the narrow gauge offers; it involves the leading principle in railway economy, but it is an economy which I have shown—and I am borne out by all the weight of the evidence given before the Royal Commission—to be impossible on the broad gauge. But it must be remembered—and this is a point not understood by some of the strongest advocates of narrow gauge—that such lines are of but little avail, unless they are provided with suitable locomotive power. If a line is made in all respects a miniature copy of a broad-gauge railway, with miniature rolling stock and miniature engine, its utility decreases, and its working capacity goes down, but its working expenses go up. In illustration of this I may quote the results of Norwegian practice, where one of the narrow gauge line, carrying only a very small traffic as compared with that conveyed upon a broad gauge in the same country, shows its expenses to be out of all proportion; while the percentages of the expenses to the receipts vary from 65.47 to 103.5 on the various narrow gauge lines now built in Norway, a result that cannot be considered favorable. If we look at the capacity of the engines on these railways, we shall see that they are capable of drawing besides their own weight, 83 tons, 55 tons, and 84 tons respectivelly, up gradients of 1 in 70, 1 in 42, and 1 in 60, and it is worth noting that the proportion of working expenses to receipts decreases as the power of the engine increases. Although many other causes besides those of mere lo-

comotive expenditure step in to interfere with results, the regular proportion is, I think, too clearly marked to be independent of this most important question. The capacities of the Norwegian stock and the maximum trains conveyed by the engines are shown in the diagram. I refer again for a moment to the results obtained by the employment of the steam-tender for dragging great loads. Mr. Sturrock found that he could, by adding a pair of steam cylinders to the tender of a locomotive, convey trains weighing one-half as much again as the maximum load carried by ordinary engines, with an extra expenditure of about 15 per cent.; and a train of any given weight can be conveyed for from 64 to 70 per cent. of the cost of such train divided into two equal parts, which means a saving in the locomotive accounts of from 30 to 36 per cent. It is argued against me, that an engine of my system is no more useful or profitable than two engines coupled together. My experience proves the contrary; so far as they go, the results with Mr. Sturrock's contrivance bear me out, and so do the results obtained by the working of MM. Moyer's engines (adapted from my own) in France. If such a system as that which I recommend had been introduced into Norway, it is needless to point out that a considerable modification of the balance sheet would have been the result. To sum up, then, the requirements necessary for making a narrow-gauge railway perfectly efficient, we must have light, small stock, easily handled, and very powerful engines, capable of drawing heavy loads. The experience of the present year entirely bears out this assertion. We need only turn to the 3 ft. 6 in. Livny railway in Russia, carrying regularly its 354 tons of train exclusive of engine, a duty accomplished by one Fairlie locomotive without distress to the permanent way, and up gradients, some of which are 1 in 80, of 4 or 5 miles in length, and with an economy shadowed forth long since by the crude appliances that were tried with a vague hope of achieving a similar result. Again, as already stated, the introduction of the same system on the Festiniog Railway avoided the necessity of doubling the line of rails (a work which was actually commenced so far as preliminaries were concerned), by more than doubling the utility of the single pair. The diagrams show the change very strikingly, the one indicating the daily duty of the "Little Wonder," the other the similar duty of the ordinary engines of rather more than half the weight. It now remains to point out as briefly as possible the circumstances that have led me to adopt a 3 ft. gauge, and to recommend that width for general introduction. Experience has shown that 3 ft.6 in. can be made a highly economical and efficient width, but it does not by any means follow that it is the most serviceable and most efficient, any more than it follows that the accidental 4 ft. 8½ in. was all that could be desired, even though an Act of Parliament had made it an article of belief. On the contrary, as our knowledge and experience increase, we are enabled to approach more and more nearly to that happy mean, on either side of which is error. While, on the one hand, there is every necessity for obtaining such a gauge as will afford a good and useful width of vehicles, on the other it is necessary to avoid such narrow limits as would necessitate the introduction of too great overhang on each side of the rails. The 3 ft. gauge appears to me to comply with all the necessary conditions better than upon any other, and it is from mere theorizing that I lend all the influence I have towards its adoption. There is a certain amount of saving in first cost as compared with the 3 ft. 6 in., not a large amount, but worth considering. This, however, I leave out of the discussion for the present. The all-important matters are to place upon the rails a thoroughly efficient stock that shall possess a maximum of capacity and a minimum of weight, and to supply engine power under the most economical circumstances, and I hold it to be easier to accomplish these objects on the 3 ft. gauge than upon any other. I am led to this conclusion both by a comparison of the actual work done on the 3 ft. 6 in. gauge, with that which can be accomplished with the 3 ft. gauge, and because, having in view the practical requirements of goods traffic, I find that I can obtain an ample floor area with less dead weight than can be secured by any other width; on a wider gauge the dead weight increases, on a narrower one the capacity decreases. A statement of the actual results of comparison will explain this more clearly and more quickly than could be done otherwise. On

the Queensland 3 ft. 6 in. Railway, the composite passenger carriages are 6 ft. 6 in. wide, and 6 ft. high inside. The capacity is equal to 34 persons, and the weight is 10 tons 500 cwt., or 600 cwt. per passenger; the second and third class carriages accommodate 48 persons, and weigh 9 tons and 2 cwt., or 3.75 cwt. per passenger. The wagons average 14 ft. in length, 6 ft. in width, and weigh 3 tons 5 cwt. The covered wagons are 6 ft. high inside, and the open wagons have sides 30 in. high; the first would have a capacity of about 7 tons, the latter of about 5 tons, the respective proportions of paying load to weight being 2.15 to 1, and 1.54 to 1. On the Norwegian 3 ft. 6 in. lines, the first class carriages are 6 ft. 10 in. wide outside and 20 ft. long, weigh 4.6 tons, and carry 32 passengers, the proportion of weight per passenger being 2.9 cwt; the second-class carriages have the same length and width, and carry 32 persons and weigh 2.4 cwt. per passenger. The covered goods wagons are 18 ft. long, 6 ft 7 in. wide outside, weigh 3.7 tons, and carry 5 tons, the proportion of freight per ton weight of wagon being 1.2; this proportion is steadily maintained throughout the wagon stock, rsing, however, as high as 1.6 to 1, while some of the more recent stock carries 6 tons instead of 5; of the increase of dead weight in these I have no data.

For a 3 ft. gauge, the stock that I construct is as follows: for first-class passengers the carriages are 18 ft 6 in. long, 6 ft. 8 in. wide inside, seat ng 18 passengers, and weighing 3 tons 5 cwt., or 3.6 cwt. per passenger. For second-class, the carriages are 16 ft. 6 in. long, 6 ft. 8 in. wide, weighing 3 tons, and carrying 24 passengers, being 2.5 cwt. per passenger; the third-class carriages are of similar size, but seat 30 people, the dead weight being 2 cwt. per passenger. It will be noticed that these proportions are nearly identical with those of the Norwegian lines, but considerably less than those of the Queensland Railway.* My open wagons are 10 ft. by 6 ft. 6 in. by 2 ft. 10½ in. high, weighing 28 cwt. 3 qrs., and having a cubic capacity of 4 tons, equal to a proportion of 3 to 1; also others for light goods, such as cotton, are 14 ft. by 6 ft. 6 in., with posts and rails 6 ft. 6 in. high from floor, or, as we are now running them in Mexico, with a low ledge running all round only 6 in. high, on which cotton bales are piled in a similar manner to that on a street wagon or Lorry and covered with tarpaulin. The covered wagons are 10 ft. by 6 ft. 6 in. by 6 ft., of 360 ft. contents, and weighing 33 cwt., equal to 3 tons of carrying capacity to 1 of dead load. In all this stock, as well as in the other classes required, the centre of gravity is kept low, and an angle of stability of 38 deg. is in all cases maintained. It will thus be seen that upon a 3 ft. gauge I am enabled to place stock of ample size and of less weight than can be done on the 3 ft. 6 in. lines. In adopting this stock, I secure several advantages inseparable from the Fairlie gauge. The principle of these is: the reduced widths between the sole bars for the under frames of wagons and carriages, and lengths of wheel centres; these in turn affect the scantlings of material, the weight of the wheels, the size of axles, to carry certain loads. It has been argued that the excess of strength over the actual requirements for carrying, but necessary to resist the shocks and concussions incident upon shunting, etc., would not be affected by the gauge; and that if the gross weight of a train is maintained upon the narrow, that is now worked on the broad gauge, the wagon frame and coupling must be alike in weight to give equal strength to withstand sudden shocks and strains. Of course this is in itself quite true, and certain parts must be as strong in a train of given weight on a narrow as on a broad gauge. The force of the argument falls to the ground, if we remember that under present circumstances an average goods train, say of 250 tons, has only 50 tons of paying weight, the remaining 200 tons being stock Now, on the narrow gauge, supposing that only 1 ton of goods was carried per truck, as in the case of the 4. ft. 8½ in. gauge, the dead weight required to carry it on my system would be only 87½ tons, making the total weight little more than half, and reducing the force of shocks upon the train in a proportionate manner, so as consequently to reduce the requisite weight of parts. Take, now, this same weight of paying load in a train, namely,

* The stock here described is on the type used in this country; a different type would require to be made to suit different tastes, as in America for instance, carriages should have a central passage and rest on two bogies or trucks, with entrances at each end.

50 tons, and place it in the same portions in the wagons of the Norwegian 3 ft. 6 in. line, or in those of the Queensland Railway, and we shall find that the dead load carried runs up to 185 tons, or a close approximation to our English practice. Probably, therefore, this stock as built is not too heavy to resist the strains and shocks thrown upon it by reason of its own weight; but by the mode of coupling employed on the Fairlie stock, the destruction arising from the shocks caused by sudden stopping and starting of the trains, especially when shunting, is entirely avoided; and as the strength and consequent weight of the present stock depends on the necessity of resisting these shocks and bumps, it follows that the instant these are removed, the necessity for all this extra strength and weight is removed also. The foregoing figures really mean that to carry 50 tons of goods on the Norwegian or Queensland 3 ft. 6 in. gauge, the proportion of 1 ton per wagon being preserved, 92 per cent. of the weight of rolling stock used on the 4 ft. 8½ in. gauge would be required, as against only 43 per cent. on a 3 ft. gauge; showing a saving of 47 per cent. on the latter, as compared with the 3 ft. 6 in., as shown in the diagram. Of course, if the wagons were loaded up to full capacity, these percentages would be very much changed. It is to this point especially that I wish to direct your attention, as upon it the economy of the 3 ft. gauge rests. Whatever saving may be effected in the first cost may be lost sight of, the great advantage lying in the saving effected in working expenses. Every ton of dead weight saved goes towards securing the prosperity of the line, and if we can obtain the ample platform which the 3 ft. gauge gives, combined with so much saving in weight, there is nothing left to be desired.

In making my comparison, I have taken matters as they exist in Queensland and in Norway. The able engineers of those lines have designed their stock as economically as they found possible. I should have thought the dead weight might have been reduced to a certain degree; but of course I am aware that no such reduction as may be made on a 3 ft. gauge could be achieved.

Before I conclude, I may refer to one or two prevailing errors which exist with regard to the narrow gauge, and which are often urged against it. It is said that with a 3 ft. or 3 ft. 6 in. gauge, a far larger amount of siding and goods shed accommodation is required. Is it not sufficient to point out, as the wagons carrying the same on the latter as on a wide gauge are but some 10 ft. long, as compared to 16 ft., that a train of the former, conveying the same loads as one on the latter, would have but $\frac{5}{8}$ths of its length? Here, again, the axion of subdivision of traffic is applicable in all its force.

Again, a common notion—and one that was strongly urged when the discussion concerning India was in progress—is that narrow-gauge railways may be constructed in difficult and hilly countries, but not on level and favorable ground. Doubtless this idea has grown from the fact that the saving of construction in the former localities is greater than in the latter. But, as I have already stated, the economy in the cost of construction is altogether subordinate to the greater and constant economy in daily use. The fact is that narrow-gauge lines are useful everywhere, are needed everywhere; the saving in their first cost rises and falls with the country over which they pass, and, always considerable, is greatest where precipitous districts demand lines that creep around and up hillsides; but the subsequent economy is not variable; it is always what I have shown it to be, when narrow-gauge railways and their equipments are worked, as everything should be worked, with a view to progress and development.

INTERNAL TEMPERATURE OF THE EARTH.

From "The Mining Journal."

It had been arranged that from the commencement of the Alpine Tunnel, observations of the temperature, at intervals of 1 kilometre (3,281 ft.), should be taken at both ends during the progress of construction. Signor Borelli, the resident engineer at the Italian side, undertook and carried out these observations very

perfectly on his part of the work; but, unfortunately, his colleague at the French end very soon lost interest in the matter, and such observations as were made were not recorded. Thus, the opportunity of comparison of two independent sets of observations, which would have been of very great value, has been lost, and this is the more to be regretted because the present data, in many respects, do not correspond with our previous knowledge of the rate of increase of heat as the distance increases from the earth's surface. The dimensions, etc., of the tunnel have been already before our readers; but, for better comprehension, we repeat them here. The total length of the enclosed boring is 40,140 ft., and the highest point of the mountain in a vertical line above it is 5,280 ft.—this point being 21,156 ft. distant from the Italian end. The rocks through which the tunnel has been driven consist, for the most part, of calcareous schist, partly talcose, and containing many bands and strings of quartz. The whole of the Italian work consisted in piercing through rock of this kind, and the same rock was met with at a distance of 11,000 ft. from the French side. All the rocks traversed are metamorphic, being, however, stratified, dipping at an angle of 50 deg., or thereabouts, to the northwest, and corresponding in age to the secondary rocks of England, from the Oxford clay to the Rhœtic, inclusive. The excavation of the tunnel from the Italian end was suspended when 6 kilometres (about 20,000 ft.) had been completed, being rather less than half way; but as the excavation from this end had been much more rapid than it had from the other, a small heading was continued to the distance of about 3,000 ft. further, when the French work from the other side was met. On the opening being completed a rush of air took place, driving the smoke of the last blast rapidly before it and towards the Italian end. It may be assumed that the tunnel will act as a kind of chimney—and that ventilation will be much assisted by an upward current of air, when it is considered that its Italian end is 4,241 ft. above the sea level, whilst the northern or French end is only 3,806 ft.—being a difference of 435 ft. in favor of a natural ventilating current. The following statement is a translation, by Prof. Ansted, of that published by Signor Giordano, who has tabulated the observations of Signor Borelli:

No. of observations.	Distance from S. entrance. Feet.	Temperature. Air. Fahr.	Temperature. Rock or water. Fahr.		Depth in feet.
1	1312	50.9°	51.8°	Small spring.	
2	1640	50.9	57.6	Boring from a heading 24 ft. from the wall of the tunnel	1500
3	3281	59.5	62.6	Boring of 16 ft. from heading.	
4	3675	59.5	62.6	Small spring	
5	6562	64 0	67.0	Boring of 10' from heading, 21½' from wall	
6	8202	64 0	68 0	Small spring	1700
7	9266	64.0	68.0	Small spring	
8	9843	68.5	73 0	Boring similar to No. 5	
9	13124	73.4	74.5	Boring similar to No. 5	
10	16404	76.1	81.5	Boring similar to No. 5	3000
11	19686	80.2	84 0	Boring of 10' in a recess 13' from wall, near the point where the excavation was suspended	4500
12	21156	86.1	85.1	Boring of 7' under the culminating point of mountain. Small heading 7' from wall.	5280
13	21858	86.2	82 4	Small spring.	
14	22967	77 0	80 6	Boring of 7' into wall of small heading.	4750
15	22993	77.0	77 9	Small spring.	

From this table it appears that the observed difference of temperature of the rock between the distance of 1,640 ft. from the entrance and the distance of 21,156 ft. is 27.5 deg. Fahr., the difference of depth beneath the surface in that distance being about 4,600 ft. If we allow for the increase of temperature of the

air due to the number of men employed, and the frequent blasting, the difference may be more safely estimated at somewhat less. The true maximum temperature of the rock may be taken at 84 deg. Fahr., and the part of the tunnel having this permanent temperature is 4,250 ft. above the sea, the corresponding point of the surface vertically above it being 9,530 ft. above the sea. The difference of the levels is, therefore, 5,280 ft. Mr. Ansted believes that a careful estimate of the distribution of the mountain mass would show this to be somewhat in excess of the true difference, and that if the slope were perfectly even, the difference of level would be about 5,080 ft. The mean temperature of the air decreases in ascending to the nigher parts of the atmosphere at the rate of 1 deg. Fahr. for each 317 ft. of ascent, and the stratum of invariable temperature in descending into the earth is nearly 2 deg. Fahr. warmer than the mean temperature of the air at the surface. The city of Turin is 820 ft. above the sea, and its mean temperature 54.5 deg. Fahr. The difference in level between Turin and the highest point above the tunnel is 8,710 ft.; this, divided by 317, gives 27.5 deg. Fahr. as the amount to be deducted from 54.5 deg. Thus, the mean calculated annual temperature at the surface of the highest point above the tunnel would be 27.5 deg., and adding 2 deg. to this, the calculated temperature of the stratum of invariable temperature would be 29.5 deg. Fahr. Estimated in this way, the difference of temperature between the mean temperature of the air on the assumed surface above the central point in the tunnel, and that point would be 84 deg. -27.5 deg. $=56.5$ deg. Fahr., and the rate of increment (the difference of level being 5,080 ft.) 1 deg. in $(\frac{5080}{56.5}) = 90$ ft. nearly; or, assuming the stratum of invariable temperature to be 80 ft. below the surface, 1 deg. in $(\frac{5080}{54.5}) = 91$ ft., thus showing a very considerable variation of result as compared with most other observations that have been made in Europe and elsewhere at various levels. Signor Borelli's observations, tabulated according to these calculations, yield the following figures:

Observation.	Distance from S. entrance—Feet.	Depth from surface—Feet.	Temperature.	Rate of increment.
3	3281	1700	62.6°	1° Fahr. in 43 feet.
5	6562	1700	67 0	" 50
8	9843	1700	73 0	" 61
9	13124	1700	74 5	" 63
10	16405	3000	81.5	" 65
11	19686	4500	84 0	" 84
12	21156	5280	85 1	" 91
14	{22967*} {18345*}	4750	80.6	" 93.4

* Feet from N. end.

NEW SURVEYING INSTRUMENTS.

From "The Iron Age."

Much attention has recently been drawn to a new form of instrument, which may be seen in Div. III. at the London International Exhibition. It is intended for gener l surveying, and from the inspection of it practical men are inclined to believe that it is very likely to supersede the ordinary kind of instruments employed for such purposes. It is the joint invention of Mr. H. D. Hoskold, of Cinderford, mining engineer, and Mr. J. E. Winspear, of Hull, optician and mathematical instrument maker, and they have designated it by the name of "Angleometer." It is particularly designed for measuring angles in the field and underground, similar to a theodolite, but in consequence of its peculiar construction it is not liable to the same amount of derangement and imperfection as that instrument—indeed, it will be found vastly superior, both in point of construction and working, and occupies

much less space. The instrument when made with a divided limb of 5 in. diameter is only $6\frac{1}{2}$ in. in height, and moreover, it is mounted with a telescope $10\frac{1}{2}$ in. in length, of high optical power, and is made to revolve vertically, and thus becomes a transit instrument of great power and capability, either for extensive surveying on the surface or underground. Furthermore, its particular form renders it well adapted to be used as a zenith telescope for performing astronomical operations of importance, and for connecting underground surveys to those made on the surface directly, by means of the telescope without magnetic bearings, rendering it for that one operation alone a most valuable instrument, which doubtless will duly be appreciated by mining men.

The whole arrangement is new, although there are some parts in it common to all superior surveying instruments, such, for instance, as the silver limb for receiving the graduations, parallel levelling plates, clamp and tangent screws, etc. In surveying instruments of the best class hitherto constructed, such as the transit theodolite, equal power and capabilities can only be obtained by additional height, weight and cumbrousness of parts, the subject of so much objection to their general introduction for mining purposes. Thus, if we take a transit theodolite, with a limb of 5 in. diameter and a telescope of $10\frac{1}{2}$ in. in length, as an *example of comparison*, it will be seen that the telescope must be mounted upon Y's, which would render it over 12 in. in height at least, besides possessing the disadvantage of having the magnetic compass very much smaller than its own limb. Every additional inch to the height of an instrument of this class proves a disadvantage, simply because all the centres and bearings must be longer, and, consequently, vibration of the parts is increased. This is more especially so when exposed to currents of air and wind on the surface, which prove very destructive to observations. It is, therefore, desirable that all these points should be kept well in view while designing an instrument. We are pleased to observe that this has been practically realized in the designing and construction of the angleometer. It appears that the length of the telescope does not regulate the height of the instrument, as in the class of transits before referred to, for a small instrument of the new type may be made to carry a telescope of equal length and power with those of some of the larger instruments of the old type, without additional height.

It will be seen by referring to the instrument in the Exhibition, that the horizontal axis carrying the telescope and vertical circle is mounted close down on low bearings, not more than $1\frac{1}{4}$ in. in height on the upper vernier plate. These bearings, axis, and all other internal arrangements, are covered up by a magnetic compass box of the same diameter as the angleometer's graduated limb. The needle of this instrument is constructed to carry a silver floating circle with verniers at each end, and it rests on a recess cut in the edge of the inner divided circle ; it is thus prevented from rocking or vibrating unduly. The needle by its verniers is capable of reading magnetic bearings, to single minutes, and will prove of very great service for determining the magnetic vibration of the compass by observation. The divided limbs to horizontal and vertical circles are graduated to 20 sec., but it is intended to divide a 5-in. to read to 10 sec.; and by the high optical power applied in the telescope to render the instrument available for extensive operations, which were formerly performed with instruments of a large and more cumbrous nature. The telescope is fixed in a stout cylindrical ring, screwed to the one end of the axis a little larger than itself, and made to rotate in it horizontally, for the purpose of collimation. The vertical circle is constructed with a conical limb, and the graduations are put on its edge, instead of, as usual, against the side of it ; there is, consequently, greater facility provided for reading angles off from it. This vertical circle is attached to the opposite end of the telescope axis, and balances and moves with it ; consequently, no vibration whatever exists in the instrument, not even when exposed to a rather severe blast of wind. At the eye end of the telescope there is a perforation, into which a piece of glass is fixed nearly opposite the cross-hairs, for the purpose of illuminating them by means of the flame of a candle or lamp when the instrument is used underground or at night. At other times a slide is turned, which effectually shuts out all light. There is also a micrometrical arrangement work-

ing mechanically in the eye end of the telescope, and communicating with two circular discs, about 1¼ in. in diameter, outside the telescope, the circumference of which is divided into a certain number of equal parts, reading by means of verniers to the 10,000th part of an inch.

The object of this arrangement is for the purpose of ascertaining distances without direct measurement, which is performed in a very simple and accurate manner. There are two cross spirit bubbles fixed below the needle in the compass box, and on a level with the face of it; they are adjusted by means of screws, which do not appear, and cannot be damaged from exterior influences, as in theodolites. A longer and more sensitive spirit bubble is attached to the verniers to vertical circle, which are dead fitted, but adjustments are provided for the bubble. A lever clamping apparatus is also attached to the vertical circle, which acts more effectually than clamping screws of the ordinary form. As angles are measured from the side, and not from the centre of the instrument, special station staffs are provided, which, in practice, works out in the same manner as though all the angles were measured from the centre of the instrument. Lamps on a similar principle are provided for underground work. The inventors of the angleometer propose to apply its principles to all and every kind of surveying instruments.

It has been applied by them to an ordinary miner's dial, one of which may be seen in the London International Exhibition, and it appears to be an excellent little instrument for the purpose for which it is intended. It has plain sights at one side of the compass box, screwed to a horizontal axis passing through low bearings, as previously mentioned in the angleometer. To the other end of this axis a semicircle is attached, and graduated on silver to read to 3 min. It will be observed, on examination, that these plain sights may be made to perform an entire revolution vertically, carrying with it the horizontal axis and semicircle at the other end of it; thus an angle may be observed at a high elevation or depression up to the vertical, in fact, or 90 deg., and in such position the sight does not interfere with reading the face of the compass. The best construction for dials hitherto has been known as Hedley's dial, but when the concentric ring of it is raised, and the sight applied to a high angle, both the sights and ring carrying them tend to prevent dispatch in reading off bearings. All these disadvantages are avoided in the construction of the new dial referred to.

The plan of connecting lines without bearings can also be performed by this dial directly by its sights in awkward places underground, where the vertical distance of connection is not too far for marks to be seen distinctly through the blank sights. Bubbles are also fixed on a level with the compass face, so that vertical angles may be measured from the semicircle to a considerable degree of accuracy. The proprietors of this invention have applied for a patent, which will very soon be completed.

It is understood that the same parties have another matter on hand, and in course of construction, which could not be completed in time for the Exhibition. This refers to a universal plotting scale, for laying down base and other lines to very great niceties.

ON THE CONSTRUCTION OF TRACTION ENGINES.

From "The Engineer."

The traction engine, or common-road locomotive, was invented before the railway locomotive. The traction engine in its best form is still a very imperfect machine. The railway locomotive, on the other hand, is unsurpassed in beauty of workmanship and efficiency by any other species of steam engine. How are these facts to be explained? It cannot be disputed that the general principles which guide engineers in designing locomotives apply to a great extent to all forms of the steam engine. We require a good boiler to generate sufficient steam; a good arrangement of machinery to utilize the steam generated. These truths should be self-evident. They are invariably acted upon by locomotive superintendents with the happiest results. We find them frequently disregarded by builders of traction

engines with the worst possible consequences. No one ever hears nowadays of a locomotive which will not keep steam. A breakdown on our railways is, as regards the locomotive, a strictly exceptional occurrence. We wish it were possible to say as much of the traction engines of 1871. No competent engineer who is not blinded by self-interest will attempt to prove that the traction engine is nearly as perfect in its way as the railway locomotive, nor yet that a degree of excellence has been reached which it is impossible to step beyond. Before the public can be satisfied, much better traction engines than any yet made must be built. We propose here to explain the reasons why the traction engine is still extremely imperfect, and to lay before our readers, as concisely as is consistent with the importance of our subject, the principles which should not for a moment be lost sight of by those who design steam engines intended to propel themselves and haul loads on our roads, and possibly on our fields.

It would be waste of time to examine here very closely the causes which have conduced to the comparative perfection of the railway locomotive. They are numerous, but one stands out more prominently than the rest. The railway locomotive has been built almost regardless of cost. We say "has been," because in the present day the greatest possible care is taken to keep down its price, both by the purchaser and the maker; but not so many years have elapsed since locomotives were built with regard to but one condition, to wit, that they should be the best it was possible to build; and this utter disregard of questions of first cost did a great deal, no doubt, if not all, to promote the progress to perfection of the machine. The best talent to design, the best materials on which to work, and the best tools with which to work, were all available, and properly so, because vast interests were at stake; but the case has been and is very different as regards the traction engine. Comparatively small sums have been spent in bringing these machines to such perfection as they possess. They have under all circumstances been made to sell. We do not use the words in an invidious sense, but with this meaning: railway companies who built their own locomotives built them to use, not to sell them. Manufacturers of locomotives, again, were formerly certain of getting remunerative prices. Not only was there a large demand, but there was practically no competition. The case has been totally different with the builders of traction engines. They have always built on speculation; they have had to do, not with wealthy companies, but with isolated individuals who have had to be educated into the belief that it was good for them to possess engines which would propel themselves on English roads and pastures. The construction of the traction engine fell into the hands of the agricultural engineer, and between agricultural engineers there is, and always has been, keen competition. It is not wonderful, under the circumstances, that the traction engine is still comparatively imperfect. The imperfection springs from two causes. In the first place, the builders in some cases do not know what is and what is not right in a traction engine; in other cases, they know very well, but they decline to adopt proper systems of construction, because they think these would of necessity involve an outlay which must be ruinous, because it would not be appreciated by the public. In this matter we believe that they are in a sense mistaken to some extent, but it is quite certain that if traction engines are not cheap they cannot be sold; and unless they can be made cheaply no sensible engineer will undertake their construction. Cheapness and efficiency are about as difficult to combine as oil and water. If as much money had been expended on the road locomotives as has been paid for experiments in traction on railways, it would be a far more useful and efficient machine than it is now, and would probably admit of being made with a profit at more moderate prices than now obtain. Whatever opinions others may hold on the subject, we are firmly convinced, by an experience extending over many years, that the locomotive is good because at first a very large sum was spent in bringing it to perfection; and secondly, because at one time large sums could be made in building such perfected engines; and that the traction engine is imperfect, because, in the first place, comparatively small sums have been spent in improving it; and because, in the second, manufacturers are not yet sure that a fair profit can be made by building engines of a superior type. Before leaving this part of

our subject we may add that on this latter point we believe them to be wrong. The demand for traction engines is in its infancy. Nothing is wanted to develop the trade to an enormous extent but the production of a thoroughly satisfactory engine. In pursuance of the purpose with which this article is written we shall now proceed to explain what it appears to us the traction engine of the future should be.

It would be very easy, with plenty of space at our disposal, to sit down and consider the traction engine under various heads. We might consider it as a steam generator, as a steam user, and as a vehicle; but all the conditions are so closely united that it is very difficult within such limits as are at our disposal to consider these points as distinctly as is desirable. It is impossible, for example, to speak of the boiler without considering the relations which its form must bear to the whole machine considered as a vehicle. We shall endeavor, however, as far as possible, to group the points we propose to discuss, in order to avoid confusion.

The work to be done by a railway locomotive is essentially the same as that done by the traction engine. It consists in propelling itself, and a greater or lesser load, from place to place, by causing the rotation of certain supporting wheels called drivers. The great difference between the two machines is, that one works on iron rails, the other on roads or surfaces very various in quality, but invariably offering a much greater resistance to transit than a railway. It has been urged that the great difference consists in the fact that railways, being nearly level, while common roads are more or less inclined, the traction engine is called upon to exert extremely variable amounts of power. But this argument is not sound, as, compared with the whole rolling resistance of a rail; the inclines on most railways of recent construction are quite as severe as are the hills on ordinary roads, compared with the whole rolling friction. Whether on the railway or on the road the action of gravity on the inclines does far more to determine the load than the rolling friction. If this last amounts to 40 lbs. a ton on a good level common road, then will the resistance be just doubled by a hill rising 1 in 56. If the rolling resistance on a level railway be 10 lbs. per ton, then will the resistance be just doubled on an incline of 1 in 224. Inclines of 1 in 224 are quite as common on railways as inclines of 1 in 56 on common roads. Our readers may rest assured that the variation in the demands made on the powers of our railway locomotives are quite as great under ordinary circumstances as those found to exist in the demands made on the powers of our common-road locomotives.

No one will dispute that the locomotive practice of this country is thoroughly successful. Seeing, then, that a strict analogy exists between the work to be done by the two engines, one working on the rail, the other on the road, it is fair to assume that the traction engine builder may learn a great deal from railway practice. We have now to consider whether this assumption is or is not based on truth. The first point of difference between the railway locomotive and the traction engine is, that the latter is geared and the former is not. The crank shaft in the traction engine always makes several revolutions while the driving wheels make one. Now it can be shown that the use of gearing is attended with many and grave disadvantages; so grave and so many, indeed, that it is worth while to consider at some length why gearing is used at all. A passenger locomotive of the ordinary construction with 6 ft. drivers cannot be depended upon to take four times its own weight up inclines of 1 in 30 at any speed. A moderately well designed traction engine with drivers of the same height will take four times its own weight up 1 in 20. When locomotives are intended to work steep inclines, they are made with small wheels, in order that the tractive force which they exert may be great. This expedient cannot be applied in traction engines, because, in the first place, the rolling resistance would be enormously increased, and because in the second the bite of the wheel on the road would be reduced. A railway engine weighing 25 tons, and taking a load of 100 tons behind it up 1 in 30, must exert a tractive force at the rails of $1250 + 9333 = 10{,}583$ lbs. If this engine had 4 ft. wheels, and a stroke of 2 ft., the distance passed over at each revolution of the drivers would be in round numbers 12 ft. 7 in., or 151 in. The two pistons would together pass over 96 in.

The mean pressure on 1 piston must therefore bear the same relation to the tractive force that 151 does to 96. It amounts, in other words, to 16,646 lbs. This divided by 100 lbs. for the pressure of steam on the sq. in., equivalent to, say, 130 lbs. in the boiler, gives us 166.46 sq. in. of piston. The pistons of our locomotive should therefore be 14½ in. in diameter at least. In practice, such an engine would have cylinders 16 in. in diameter and 22 in. stroke, instead of 24 in.

Now a traction engine weighing 10 tons, and hauling 40 tons behind it up 1 in 30 on a good common road, must exert a tractive force of 2000 + 3735 = 5735 lbs. The drivers of such an engine should not be less than 6 ft. high. Let us assume that they are a shade under, and that the circumference of the wheels is 18 ft.; let us further assume that the pistons are coupled directly on to the driving axle without the intervention of gearing, and that the stroke is 18 in. Then for each revolution of the drivers the pistons will pass over 6 ft. The mean pressure on one piston must, therefore, be three times the tractive force exerted at the road, or 17.205 lbs.; dividing this by 100 lbs. pressure as before, we get 172 as a quotient. This answers to a cylinder a little over 14¾ in. in diameter. In practice, such an engine would have a pair of cylinders 6½ in. or 7 in. diameter and 10 in. stroke, geared down to the road wheels about 10 to 1. We have, as far as possible, put this comparison between a road locomotive and a railway engine in the clearest and simplest form, because we are aware that very confused notions exist, among many young engineers especially, as to the conditions under which engines haul loads, and the proportions which should be observed in designing them. We have thus considered the case of two engines doing the same relative duty; it now remains to be seen why gearing should be used in the one engine and abandoned in the other.

It is, of course, obvious that if gearing be dispensed with in traction engines, motion must be communicated to the driving wheels in one of two ways—either the driving axle must be cranked, or else pins must be fixed in the wheels for the connecting rod ends to lay hold of. It is very necessary in designing road steamers or traction engines that the driving axle should nearly coincide in position with a vertical line passing through the centre of gravity of the machine. In other words, the driving wheels should carry about 7-10ths of the whole weight, or even a little more. If a vertical boiler is used, with vertical cylinders over the cranked road-axle, as in the Thomson engine, it will be almost, if not quite, impossible to secure this object. The cranks must clear the boiler, and the latter will be thrown too far forward. Besides this, however, there is a great objection to the use of vertical cylinders in this way, the action of the steam causing the engine to jump up and down and roll about. This action is not—for reasons which require no explanation—manifested to the same extent when vertical cylinders are used with gearing. The distribution of weight might be managed pretty well with vertical boilers and cylinders if outside cranks were used. But then the cylinders would be thrown out very far from the boiler or any other basis of support, because of the great width of the road wheel rims. If the locomotive type of boiler be employed the cylinders must be put under the boiler, which is not in itself objectionable. Engines of small power have been made in this way with some success. There are, however, other objections to the direct system to be considered. In the first place, the cost of the crank-shaft must be very considerable, and its weight, and that of all the parts of the machine connected with it, must be very much augmented. The dead pull and push on each cylinder cover will be so excessive that very heavy fittings will be required to secure the cylinder in place. The use of these large cylinders without expansion would be extremely objectionable on the score of economy; but it would be impossible to have proper expansion with a plain slide valve, unless so large a lap was used that the engine would be constantly liable to "go blind;" and in climbing steep hills, or in positions of difficulty, the propelling force would vary very much throughout each stroke, a point to be of all things avoided, for reasons which we shall explain further on. It is not necessary, we think, to dwell on other objections, such as the weight and cost of the cylindes, the irregular action of the blast in the chimney. We have said enough to show that, except for high speed or pleasure

carriages, gearing must be used. But against gearing, in its turn, very serious objections may be urged. Its presence increases the cost and weight of the whole machine. It is peculiarly liable to fracture; the gearing is all but invariably the seat of every break-down that takes place. In order to keep it light it must be kept small, and thus engines may be found transmitting 40 or 50-horse power through cog-wheels 2 in. wide on the face and $1\frac{3}{4}$ in. pitch moving at a comparatively slow speed. Only the best possible materials and first-class workmanship can secure immunity under such conditions from the continual recurrence of accidents, and so we find that steel or malleable cast iron is being used in the gearing of all really good traction engines. But these materials cost a great deal of money, and it will be found that a point is soon reached beyond which the balance of advantage might lie with the direct system; if only the difficulty concerning the want of equality of action could be got over. This might be disposed of by the multiplication of cylinders, and there is little room to doubt that *in the abstract* a better traction engine might be constructed with 4 cylinders each $10\frac{1}{2}$ in. in diameter and 18 in. stroke, driving the crank shaft direct, than one with two $6\frac{1}{2}$ in. cylinders, 10 in. stroke, and a lot of gearing; but the cost of such an engine would be much more considerable than that of the geared engine, and its weight would, on the whole, be perhaps greater. Whatever theoretical view may be taken of this subject, it is certain that in practice, and under the ordinary conditions of trade, gearing of some kind must be adopted in traction engines.

The gearing used in traction engines may be classed under three heads: (1) spur gear; (2) chain gear; (3) chain and spur gear. In very light pleasure carriages gut bands have been employed, and in some of the American steam-propelled street cars—called "dummy locomotives"—leather belts have been used to communicate motion from the crank-shaft to the road wheels; but it is unnecessary to do more than mention expedients only applicable in very exceptional cases. We shall, therefore, confine ourselves to the consideration of those systems of construction which are habitually employed, or have been resorted to with some success.

Before deciding on the arrangement that shall be adopted in communicating motion from the crank shaft to the driving wheels two things must be taken into consideration—firstly, the relative positions of the two shafts, and, secondly, the first cost to be incurred. The relative angular velocities of the shafts have very little to do with the matter, because, within the limits of velocity of rotation which obtain in traction engines, either chains or gearing, or both, can be employed. As regards the first point, it may be laid down as an axiom that the use of "idle" wheels is to be deprecated; as regards the second, it is certain that a properly made chain costs more than the spur gear to which it is the equivalent. Messrs. J. Fowler and Co., of Leeds, use spur gearing in which an "idle" wheel forms an important part in their ploughing engines. But it must be remembered that these are self-propelling engines, not intended to haul loads. Their propulsion is altogether a secondary consideration. Their principal work is done in causing the rotation of the winding drums below the boiler; and the position of this drum is such that of necessity the driving wheels must be kept well back to clear the rope, while the crank-shaft must be kept well forward to suit the position of the vertical shaft at the front corner of the fire-box. A glance at the engraving published in "The Engineer" for July 21st, page 36, will make our meaning perfectly clear.

In designing a traction engine it will not do to leave everything open; some fixed point of departure must be settled upon. This point should be the tractive force which it is intended the engine shall develop. To go no further back, it has been proved at Wolverhampton that an engine with elastic tired wheels will possess sufficient adhesion to haul a gross load including the engine, of five times the load on the drivers, up 1 in 18 on a good road. Let us take it for granted, however, that the maximum load to be moved is five times that on the drivers up 1 in 20. Let us also assume that our engine shall weigh 10 tons, of which 7 are carried by the drivers. The total load will then be 35 tons, and the net load 25 tons. Let us further take the resistance due to what is called road friction to be 40 lbs. per ton, then it is clear that the tractive force exerted at the surface of the road must be 1400 lbs. to overcome road resist-

ance, and 3,920 lbs. to overcome the resistance due to the incline of 1 in 20. The total tractive force to be exerted must therefore be 5,320 lbs. Once in possession of these figures we are in a position to settle the diameter of our cylinders, their stroke, and the ratio of gearing we shall adopt with any given boiler pressure. We are indebted to Lieut. Crompton for the following formula embracing the solution of the entire problem thus stated, and making an allowance of about 30 per cent. for engine friction, including of course that of the gearing:—

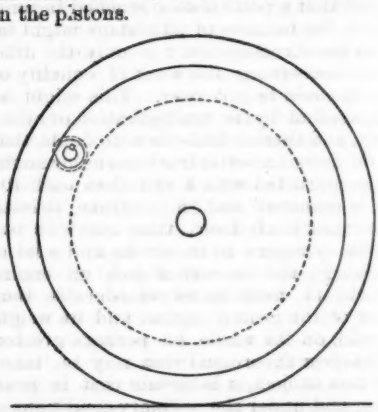
Let A be the area of one cylinder in inches, let p be the average pressure throughout the stroke, S the length of stroke in inches, R the ratio of gearing, C the circumference of a driving wheel in inches, T the tractive force in pounds.

Then $T = \frac{8 A p S R}{3 C}$.

Further on we shall show reasons for abandoning the existing system of very small cylinders and very high pressures. Let us assume that we shall have in our 10 ton engine two 8 in. cylinders, with a stroke of 10 in.; that the average presure in the cylinders is 75 lbs.; that the velocity ratio of the gearing is 12 to 1, and that the driving wheels have a circumference of 226 in., corresponding within a minute fraction to a diameter of 6 ft. A piston 8 in. in diameter has an area of a little over 50 sq. in. Substituting these figures in the formula, we have

$$\frac{8\times50\times75\times10\times12}{3\times226} = 5310 \text{ lbs., omitting fractions.}$$

An 8-in. piston is a shade over 50 in. in area, and, taking this into consideration, it will be found that the result given by the preceding calculation comes quite close enough for all practical purposes to the required conditions. A pressure of 100 lbs. in the boiler, we may add, should give more than the average pressure required in the cylinder if the cut-off took place at half stroke. It may be as well, before proceeding further, to state the velocity of the engine for a speed of 2½ miles an hour—quite enough, perhaps, for the load on an incline so steep as 1 in 20. A driving wheel 6 ft. high will revolve 280.3 times in passing over a mile. As our driving wheel is a shade under 6 ft. high, we shall take the revolutions in round numbers. Therefore, in traversing 2.5 miles it will make 700 revolutions. This divided by 60, gives us 11.66 as a quotient, and this multiplied by 12, the ratio of gearing, gives us very nearly 140 revolutions per minute of the crank shaft. From this it will be seen that with a speed little in excess of that adopted very generally in portable engines, we can obtain with an engine such as we have described, a fair speed on the road with a very heavy load. And it must be remembered that Lieutenant Crompton's formula is based, not on theory, but on the results of a great many experiments made with Thomson's engines, and is therefore reliable, as any of our readers will find by checking it with the ordinary formula, which assumes the shape :—as space passed over by driving wheels in one revolution is to space passed over by pistons in the same time, so will the tractive force be to the force exerted on the pistons.



The engine which we have sketched out in its three important properties, viz.: height of driving wheel, ratio of gearing, and cylinder capacity, differs in two important respects from what we may call the fashionable engine of the day—that is to say Thomson's. There we have small cylinders, an exceptionally high pressure of steam, and a velocity of crank-shaft rotation without any parallel in engines intended to do heavy and continuous work. In our engine, on the contrary, we have large cylinder capacity, a moderate, but yet not slow speed of piston—about 56 revolutions per minute per mile per hour. As regards the advantages conferred by using a large instead of a small cylinder, we shall have something more to say when we come to consider the question of boil-

er pressure. The advantages of a moderate speed of rotation in the crank shaft should by this time be well understood by all engineers; by none are they more fully appreciated than by those who have had most to do with high-speed engines. This is a point, however, on which we must not stop to dwell. We hold that it may safely be laid down that an engine with two cylinders, running at 140 revolutions or thereabouts when the load is moving at 2½ miles an hour, will be competent to get out of any difficulties in which it is likely to be placed, and will prove itself thoroughly efficient and economical.

If our opinions express, as we think they do, the truth, it follows that gearing in ratio of 12 to 1 will suffice—if it be not the best possible ratio for *most* traction engines. But our readers must not fall into the error of supposing that we assert it to be the best possible ratio for *all* traction engines. If the track to be traversed is very bad indeed, like some of the so-called roads in Scotland, which in winter resemble the bed of a torrent more than anything else, or if inclines of more than 1 in 18 are likely to be met with, then it will be well to increase the ratio to as much as 14 or 15 to 1, but beyond this it is seldom necessary to go. On the other hand, if the track is exceptionally level and good, as, for example, in some districts in France, where inclines of 1 in 30 are not exceeded, a less ratio, say 7 or 8 to 1, may be adopted. The designer must suit his engine to the circumstances under which it is to be employed. Under the conditions which usually obtain, a ratio of 12 to 1 will, we think, be found most convenient.

We have now to consider whether, in using such gear, we shall do it at once, or do it at twice; in other words, shall we, or shall we not dispense with a countershaft? Now the saving to be effected by dispensing with the countershaft is enormous. We at once get rid of something not much short of 5 cwt. of extra weight in heavy engines, and from 1 cwt. to 3 cwt. in light engines; we also get rid of another seat of breakage; we save in the first cost of the machine, and in the consumption of oil and brasses, and, finally, we dispose of a shaft which is continually obtruding itself in the way of the designer on paper, and of the driver on the footplate—at least as regards engines of the Fowler, and Aveling, and Porter type. If two speeds, fast and slow, are adopted, however, the countershaft is convenient. Shall we, or shall we not, have 2 speeds, say, 14 slow and 8 fast, or any other ratio? In our opinion, the balance of advantage is against two speeds, because it introduces a second set of wheels, unless they are adopted in a way to which we shall refer presently. If sufficiently large cylinders are used, all the advantages of the slow speed can be had without its disadvantages. Suppose the engine makes 56 revolutions per mile per minute, then at 5 miles an hour we have 280 revolutions, and steam cut off at a quarter stroke; at 2 miles an hour we can use it nearly full stroke. The high velocity of the engine is not at all so objectionable when expanding as when working steam full stroke, but most of the small cylinder engines work nearly full stroke at 300 revolutions in slow gear. Let us take it for granted that our 10-ton engine, the proportions of which we have so far reasoned out, is to be of either of two types, that is to say, either single-speeded 12 to 1, or double-speeded 12 to 1, and some quicker speed, an arrangement very suitable for a road moderately level for the most part, but including 2 or 3 inclines of 18 or 20 to 1. We cannot do better at this stage, having got so far, than indicate the general arrangement of engine we would be disposed to adopt, and give our reasons for adopting it afterwards. As regards the proportions of the cylinders, gearing, and driving wheels, we have already spoken. We have now to consider the position of the relative parts.

The boiler in our engine would be of the locomotive type. As to its proportions we shall speak by and by. The cylinders placed in the smoke-box somewhat, but not quite as in a locomotive; they are to be kept as high as possible. The driving-wheel axle is to be placed under about the middle of the boiler barrel. The engine will run fire-box first. A glance at the engraving of Burrell's engine, in our impression for July 21st, will explain our meaning. The slide bars, etc., must be carried over the shaft, inclined cylinders, as in goods locomotives, being strictly admissible. Two wrought-iron side frames extending from the smoke-box to the fire-box will be em-

ployed to carry the road axle and the crank shaft. The crank shaft will be placed well up toward the fire-box. If the engine is single-speeded each road wheel will carry an ordinary geared ring, as in the Thomson engine, 5 ft. diameter on the pitch line. The crank shaft will carry two pinions, one at each end, either or both of which can be thrown out of gear. These pinions must be 5 in. in diameter on the pitch line, and will have 8 teeth 2.45 in. pitch and about 3.25 in. wide. If made of steel and properly fitted these pinions will be strong enough to transmit the whole power of the engine. As the crank shaft, also of steel, should not be less than 3¼ in. diameter, the pinions must be made with a heavy flange or shroud, to afford strength and take the fast feather in the crank shaft. We shall then have gearing speeded 12 to 1, and we can fix the driving shaft on which the wheels will revolve, and which may be bent down out of the way of the slide bars. If, however, we elect to have two speeds, then the cogged rings must drive the main road wheel axle, which will then revolve. The road wheels may have motion imparted to them from the cogged rings, either by a pin, as in ordinary engines, or by a friction strap. The slow speed will be got as before. The fast speed will be got by making the cogged ring at one side with external instead of internal teeth, and proportionately reducing its diameter. The pinion may also be made a little larger. The annexed diagram will illustrate our meaning. The full circles show the slow speed at the near side of the engine; the dotted circles show the fast speed at the far side, the large ring shows the road wheel. The arrangement is simple and mechanical in all respects but one, viz., the small diameter of the pinion; but with proper workmanship and material this evil is not nearly so great as it appears at first sight, and cannot possibly, we think, equal the objections which obtain against the use of a countershaft. Both the pinion and the ring are shrouded, which much augments their strength, and it must not be forgotten that a pinion rolling inside a circle works to far more advantage than one working outside. Another objection is that only one pinion can drive at a time, but the internal ring can be made a little larger in diameter than 5 ft., and the pitch proportionately augmented.

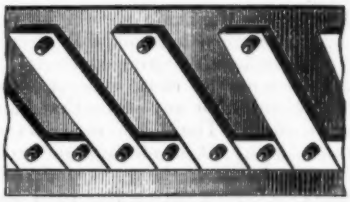
So far we have only spoken of spur gearing in its simplest form, and we may add that we are by no means certain that spur gear is the best that can be used; on the contrary, our predilections are all toward the use of chain gear.

One great point in favor of chain gear is the facility which it affords the designer for placing his engine on springs. The crank, or countershaft, or both when both are used, must be fixed in position with relation to the boiler and the framing or saddles. They cannot be fixed in relation to the driving wheels unless resort is had to very complex expedients, such as those adopted years ago by James, and more recently by Barrans. If it were possible for the crank shaft or countershaft, with its or their bearings to move up and down through the range of the springs in arcs concentric with the toothed wheels fixed on the driving shaft, all would be well, but this, from the nature of things, is impossible consistently with simplicity. Even if it could be done, the action of the springs would be so far tramelled that they would be deprived of some of their utility. If the crank or countershaft move up and down in vertical lines it is obvious that the depth to which the teeth of the gearing interlocks must vary continually; and this is not all, the presence of springs implies a certain liberty for longitudinal motion in the shaft in the direction of the axis of the boiler—if that be horizontal—which would be fatal to the permanence of the gear. If we adopt a chain the whole difficulty is got rid of. If the axis of the chain pinion and that of the chain wheel are nearly on the same horizontal line, the latter may play up and down through some inches without effecting the action of the chain, and the slight amount of slack invariably present in the latter permits a liberty of longitudinal motion in the driving axle, otherwise unattainable. When the chain pinion is carried high over the driving axle, as in Aveling and Porter's engine nearly all this advantage is lost. It may be laid down as a rule that springs cannot be combined with chain gear if the angle made by the line of centres of the chain pinion and the chain wheel exceeds 45 deg. At a less angle than this, Burrel used india-rubber springs over his driving axle with con-

siderable effect. The action of the spring is, however, not at right angles to the road, but at right angles to the line of centres. To derive full benefit from a chain it should be put to work with the line of centres as nearly as possible horizontal. It will be urged, perhaps, that springs are not needed in traction engines; this is a complete mistake. In the earlier days of the railway locomotive springs were not used. A locomotive without them in the present day would be looked upon as a mechanical absurdity. It is quite true that traction engines for slow speeds get on without them, but they are absolutely essential at speeds above 4 miles an hour. They not only assist in saving the machinery from many rude strains and shocks, but they increase adhesion, and reduce the resistance of the engine itself regarded as a vehicle. Strange as it may seem, their presence is directly conducive to economy of fuel. On rough roads, the fires in engines without springs get wonderfully knocked about, and the small coal is sifted through the bars in a way which must be seen to be believed. A case came under our own knowledge in which the consumption of fuel was increased over 15 per cent. by slightly increasing the width between bars previously placed so closely together that some trouble was experienced in maintaining a draught. Any one who will examine the contents of the ashpan of a traction engine with springs, and of one without, after running a couple of miles on a hard road at a fair pace, will be able to form an opinion on this subject for himself. Of course, if Thomson's, or some other elastic wheel be used, the necessity for springs is nearly removed; but no one who has experienced the beautifully easy floating motion experienced when the Thomson tire is combined with even stiff axle springs, will like to discard the latter without very good cause.

The second fact in favor of chain gear is that when it is properly made it is much less likely to break down under a heavy strain than spur gear. In the best constructed spur gear not more than 2 teeth in each wheel can be at work at the same time, and to all intents and purposes the whole force of the engine must be transmitted, as a rule, through a single tooth at a time. When a chain is used the case is different, as it is in wrapping contact with the wheels. The strain to which it is subjected is diffused over a number of teeth, just as in a belt the strain is diffused over most of the surface of each pulley instead of being concentrated on one or two points. Of course much of this advantage, especially as regards the chain pinion, may be lost if the pitch of the chain is unequal, and the teeth with which it gears are badly shaped; but if the entire gear is well made to begin with, a natural adjustment takes place as the parts wear, and the breaking out of a tooth is, under these circumstances, almost unheard of. The chains may break, or the chain pinion or chain wheel may be split, but the gear will not strip.

The great objection to the use of the chain is its tendency to lengthen when in use. There are three different varieties of chain employed by builders of traction engines, which we illustrate in the accompanying diagrams, but the general principle of construction is the same in all—in every case the chain resembles that of a watch. The first kind of chain consists

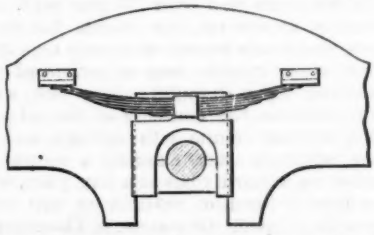


of side plates and cross pins only. No worse form of chain can be used, because the bearing surface of each pin is so small that it is certain to wear out rapidly. It is obvious that this must be the case, because the wearing surface of the pin—that is to say, that portion of it which comes into contact with the teeth of the chain wheels—can be no longer than the space between the inner links. Increased surface could only be got under the conditions either by making the pins inconveniently thick or inconveniently long. For various reasons on which we have not space to dwell, the chains should always be made as narrow as possible. A far better form of chain is that shown in Fig. 2. Here every second link is a solid block, to begin with, near each end of which a hole is drilled for the

pin. This is the form of chain used by Messrs. Aveling and Porter. The pins do not come in contact with the teeth, the ends of the blocks taking their place. With the same total width of chain, the length of bearing surface becomes the same as that of the pin in Fig. 1, increased by the thickness of the two inner links. It has hardly yet been settled whether the pins should be fast in the blocks and loose in the link, or *vice versâ*. We prefer to fix them in the side links by riveting them up tightly against the shoulder. A third form of chain, lighter and cheaper than the last, is shown in Fig. 3. Here straps welded up take the place of the blocks. Such chains work very well indeed after they have stretched and come to a bearing, but they are hardly so good as the Aveling chain. Within the limits of such a series of papers as these it would be impossible to treat properly of the correct form of tooth to be used with chains. Our readers will find the subject dealt with in Rankine's "Machinery and Millwork," p. 190. Under no circumstances should more than five teeth be used in the chain pinion.

In all cases the chain should be made as light as is consistent, not with strength, but with sufficient bearing surface. That being present, the chain is certain to be strong enough for any strain that can be thrown on it. There are three ways of using a chain. It may be applied to drive a counter shaftfrom the crank shaft, which countershaft then drives the road wheel by spur gear, or it may be employed to drive the road wheels direct from the crank shaft, or direct from the countershaft, which is then driven by gearing. The first arrangement is extremely defective; in it we have a light chain running at a high speed, which is wrong, and we sacrifice besides all the benefits to be had from the use of chains as enabling us to use springs, unless, indeed, some such arrangement as that exhibited by Tuxford at Wolverhampton this year is used. In all cases, however, it appears to be best to use a good strong chain running at a slow speed to drive the road wheels direct from the countershaft. It may also be laid down that when a chain is used it must be accompanied by a countershaft if the velocity ratio of the gearing is to much exceed six to one. The pitch of the chain cannot be kept as fine as the pitch of spur gear. A 5-toothed pinion cannot, in an engine intended to do hard work, be much less than 8 in. in diameter, which, with a 5 ft. chain wheel, would give a velocity ratio of 7.5 to 1 only. The following is a very good combination:—With 6 ft. drivers the chain wheel is 4 ft. in diameter, the chain pinion on the countershaft is 12 in., so that the countershaft makes 4 revolutions for 1 of the road wheels. In fast gear, the crank shaft makes 2 revolutions for 1 of the countershaft; in slow gear it makes 3¼. The ratio of gearing is, in the first instance, 8 to 1; in the second, it is 13 to 1.

We have stated that one of the principal objections to the use of chain gear is that the chain gear becomes slack, and requires to be tightened up; the slackness results from wear in the pins and links, and if it were not compensated for by wear in the teeth of the pinion and chain wheel the pitches of the two would not coincide; as it is, the pinion, having much less surface, wears out a good deal faster than the chain wheel, and it is not a bad practice to suppress every second tooth in the chain wheel to insure more equable



wear. A good chain, laterally stiff, will run very well, even if it is very slack; but when the pins have worn so much that its lateral stiffness is much diminished, it is liable to come off when run pretty fast, therefore some expedient for taking up wear is essential. There are numbers of these in existence; the best plan consists in moving the axles of the chain wheel—that is, the driving axle—and that of the chain pinion—the countershaft—further apart. The usual plan is to move the countershaft as in the Aveling engine. This is effected by taking liners from above the brasses and putting them below. When a single stud is used instead of a countershaft on which the chain pinion turns, a nearly similar arrangement is

adopted. The plan works very well, but we have reason to think that it would be better to move the road wheel axle a little further back. The range of motion required is very small, shifting one of the shafts through half an inch will take up the whole chain 1 in., because both sides of the chain are tightened at the same time. A total range of 1 in. in the distance between the axles will generally suffice. By the time that is used up, the chain will have augmented sufficiently in pitch to permit the chain pinion to be changed for one a little larger in the body; or the range of motion may be increased so far, that when it is all used up a link may be taken out of the chain and the bearings shifted back to their original position. There are several ways in which the shifting of the axle may be effected. We illustrate one in the accompanying diagram. Here it will be seen that the main axle runs in brasses—or, more strictly, cast-iron blocks lined with brass—which play up and down in angle iron horn-plates on the side frames. These cast-iron blocks have more metal at one side than the other. To begin with, the thin side is put to the front. After the chain has worn sufficiently, the engine is jacked-up and the blocks are taken out and turned the other way round, by which means the wheels are shifted back half an inch. When the wheels have to be shifted again, new cast-iron blocks are used, with the brasses disposed still more to one side. As the spring always finds a bearing over the axle centre the change does not affect its action in any way. The arrangement is cheap and simple, and very efficient. There are many other devices for securing the same end, on which we need not stop to dwell. We have now briefly discussed the principal features of the traction engine, considered as an engine only.

The best traction engine which it is possible to build is useless without a good boiler to supply it with steam. This fact should be sufficiently obvious; and yet an examination of the history of steam propulsion on common roads will show that it has been systematically neglected. The first engine that ever ran on a road was invented by Cugnot, and tried in the year 1770. It could only run for a about a quarter of an hour continuously, and had then to stand for about the same space of time to get up steam again. This was a bad beginning, and for very many years after Cugnot's time the want of boiler power retarded the introduction of steam on common roads. If any of our readers will but glance at the engravings published in any treatise on the steam engine showing road locomotives, he cannot fail to be struck with the obvious inadequacy of the means provided to secure the required end. We have stage coaches propelled by large cylinders, the boiler occupying no more space than the "boot"; we have omnibuses just as well provided with cylinders, the boilers consisting of a few tubes, and a fire-box which would hold about a hatful of coal. It is not a matter for surprise that such machines were failures. Even in the present day boilers far too small for their work, or improperly designed, are adopted without hesitation by engineers who ought to know better. This is not and has not been done without reason, and the reason is easily found. The boiler is an extremely inconvenient feature in road steamers, traction engines, or steam omnibuses. If of proper dimensions it takes up a great deal of room, and is very heavy. Therefore persistent attempts have been made to reduce its weight and dimensions, and the notion has obtained that by increasing the working pressure the dimensions of the boiler might be reduced. We have heard it urged that by doubling the pressure a boiler might be halved in size, still retaining the same power. If this were true, then a boiler about the size of a quart pot, heated by a spirit lamp, and worked at 1,000 lbs. on the sq. in., would suffice for all ordinary purposes. The great lesson has yet to be learned, we fear, that as in locomotives and marine engines, so in traction engines, ample boiler power must be provided before any satisfactory result can be obtained.

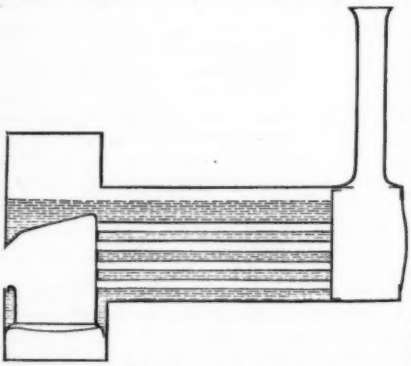
No locomotive superintendent ever troubles his head now as to the type of boiler he will use. No designer of traction engines sets to work with bow, pencil and square, without inward misgivings as to the relative merits of horizontal and vertical boilers. Whichever he selects, he will, he fears, be sorry he had not chosen the other. For ourselves, we have no doubts on the matter; the experience of locomotive superintendents, extending over a period of nearly forty years, has demon-

strated that no type of boiler is so suitable for the purposes of locomotion as that ordinarily used on our railways. What is true on the rail is true on the road. We give an unqualified preference to the locomotive type of boiler for traction engines. There is not a single argument that can be urged against it possessing the smallest weight but one. When descending steep hills the top of the fire-box may be left bare of water. The evil is purely imaginary. In our own experience we have never so much as melted out a lead plug from this cause. Messrs. Aveling and Porter, who use only the locomotive type of boiler, never experience any trouble from this source. Even Messrs. Fowler and Co. of Leeds, whose ploughing engines have often to stand on steep inclines for hours together, adhere to the horizonal type. As regards the subject with which we are dealing, the traction engine proper, not the self-propelling ploughing engine, it is evident that at the time risk is run of burning the top of the fire-box when running down hill, little or no steam is needed. If the hill is a long one it suffices to put a little fresh coal, equally distributed, over the grate, and to open the fire-door; the box cannot then be overheated. On short hills opening the fire-door will suffice; but it does not follow from all this that we should use in the traction engine a boiler *proportioned* exactly like that of the locomotive; on the contrary, as the conditions under which a traction engine works are somewhat different from those under which a locomotive performs its duties, some alterations must be made in the boiler; but these alterations are simply changes in detail, not in principle.

In the first place, as the engine must be prepared to work on inclines unknown in railway practice, means must be adopted to guard against the fire-box crown being left bare when descending them. It is therefore expedient to carry a good depth of water over the fire-box on a level. This can be effected either by working the boiler very full of water, or by keeping the fire-box very low. If we adopt the first plan we run the risk of priming, if the latter we reduce the space available for the insertion of tubes. A combination of the two plans appears likely to give the best result. The back part of the internal fire-box should be lowered, and the external fire-box should be kept high with regard to the barrel, or else a steam dome should be fitted to the latter. No locomotives work steam so dry as those with domes, and if it is found worth while to admit them on our railways, they will be found still more useful on common roads. On our railways nothing but very pure and good water is ever used. The traction engine has to make steam of any water that comes to hand. The use of a high, narrow dome is the best possible means of preventing water entering the cylinders. It may be dispensed with, however, if its equivalent in the shape of a raised fire-box shell is adopted. The accompanying diagram will illustrate our meaning better than a long description. The barrel here is kept low on purpose to allow plenty of tubes to be put in, and it is worked nearly full of water. This secures a good depth over the top of the fire-box, while ample steam space is supplied by the raised crown of the outer shell ; under such circumstances no steam dome is needed. However, for ourselves we prefer a boiler flush from end to end, as being simpler and cheaper to make, with a tall, narrow dome near the chimney. The principal point to secure is that the fire-box crown shall have plenty of water over it when the engine stands on a level. If this is the case there is no danger of burning the fire-box crown going down hill, provided the barrel of the boiler be not too long, and as this mistake is never committed by builders of traction engines we need not further refer to it.

We have now to consider what the dimensions of the boiler should be for a given power, and that this is after all possibly the most important point that can be discussed. The moment we come to consider it we discover why it is that the vertical boiler cannot compete with the horizontal type. The grand defect of the former is that, under the given conditions, as much heating surface cannot be got into it as into the locomotive boiler. There is, indeed, one vertical boiler which competes successfully with the horizontal on this basis, supplying more heating surface, of the best quality too, in a given space, than any other with which we are acquainted ; but inasmuch as this boiler has not yet been used with traction engines, it is unnecessary to say more about it than that in some respects it resembles

the boilers used by Messrs. Shand and Mason in their latest designs. Those who have read these articles attentively will remember that we proposed to adopt in our theoretical 10 ton engine cylinders 8 in. in diameter by 10 in. stroke, the diameter being considerably greater in proportion to the commercial power than that used by any maker at present. We shall assume as before that 140 revolutions are made per minute when the engine is travelling at 2½ miles per hour, and that the average pressure in the cylinder is 75 lbs., or, providing for back pressure, let us say, to be on the safe side, 80 lbs. per sq. in. At 140 revolutions the engine will use 560 cylinders full of steam per minute. The contents of each cylinder, including clearance and ports, may be taken as ⅓ of a



cubic foot. Therefore the whole consumption per minute will be a little less than 186 cubic ft. per minute, or per hour 11,220 ft. The volume of steam at a total pressure of 80+15=95 lbs., water being 1, is 280.5 ; consequently, to supply 11,220 cubic ft. of steam per hour, we must evaporate 40 cubic ft. of water. Now a good locomotive boiler properly fired, and with an adequate draught, will evaporate about 1 cubic ft. of water per hour for every 5 ft. of heating surface, consequently our boiler must have at least 200 ft. of surface; less than this can be made to do, but it cannot be made to do with economy. A striking instance of the defects of the vertical boiler is supplied by the case of the Chenab, shown at Wolverhampton. This engine had but 109 sq. ft. of surface to supply two cylinders. Aveling and Porter's 6 horse engine had 109 sq. ft. of surface to supply 1 cylinder, somewhat less in diameter, the piston speed being nearly identical. The boiler of the Chenab was made still worse by feruling up the tubes until the draught was reduced. But it appears from this it is obvious either that Messrs. Aveling and Porter give a great deal too much surface, or the Chenab had far too little ; the results of the tests, which have already been fully reported in our columns, justified Messrs. Aveling and Porter's practice. If builders of traction engines would lay it down as an invariable rule, that 5 sq. ft. of heating surface must be used to evaporate one cubic ft. of water, they would never have to complain of want of steam, provided the boiler is otherwise right.

Only one other point connected with boilers remains to be discussed here, viz., the pressure to be carried. This should in traction engines never exceed 120 lbs.—100 lbs. is to be preferred. Higher pressures are only adopted because the cylinders used are too small. The extra weight introduced into a pair of cylinders by increasing their diameter from 7 in. to 8 in. is nothing compared to the weight and cost incurred in making a boiler fit to carry 140 lbs. instead of 100 lbs. We shall return to this branch of the subject.

It is not more certain that the best arrangement of machinery which put together constitutes a traction *engine* is useless without a good boiler, than that it is useless without good wheels. We have dealt with the engine, the gearing, and the boiler. We have now to treat of the wheels, a subject which has attracted a great deal of attention from mechanical engineers during the last couple of years.

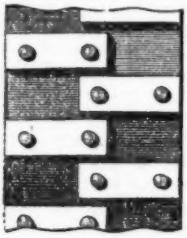
The first wheels used with traction engines appear to have been made of wood, of considerable width, and shod with strips of iron. They closely resembled ordinary gun-carriage wheels. Then came wheels with wrought-iron spokes and cast-iron rims. Next, wheels all of wrought iron, except the hubs, were tried. The latest improvement is the Thomson wheel with india-rubber tires. In dealing with this branch of our subject we shall speak only of what may be termed commercial wheels, that is to say, wheels which have been, or are, used with success in daily practice. It is quite beyond the scope of this article to speak of the hundreds of devices which have been proposed from time to

time to secure adhesion and elasticity. Passing over these, we may state that the wooden wheel had many advantages which long made it a favorite with a few builders of traction engines. In the first place, wooden wheels possessed no small elasticity. Made, as they were, without continuous tires, they flattened on the road, slightly it is true but still with benefit, by the springing of the timber felloes, which were shallow in proportion to their breadth. Each spoke, too, was in a sense a spring, or at least a very efficient deadener of vibration. The wooden wheel, again, was silent. It did not ring as it crossed gravel or broken stones, and this was a much more important point than is generally believed. As regards adhesion, if the iron tire straps were properly fitted with projecting rivet heads, it was quite equal to, if not better than, any iron wheel. The wooden wheel was, however, open to serious objections. It was expensive if proper materials and modes of construction were adopted; and it was very difficult to make it strong enough to carry the increased loads gradually adopted by engineers. The material, too, was peculiarly susceptible to climatic influences; for these reasons no wooden wheels are now used by makers of traction engines, at least as drivers, although they are retained with advantage in certain cases, by Messrs. Aveling & Porter, and one or two other firms, for leading wheels, for which, as the loads are light, the material is well suited.

Wheels made wholly of wrought iron are little used, and then so far as we have seen only in small engines, such as Aveling & Porter's "Steam Sapper." That such wheels are, when well made, very good is certain; but, unless they are used in conjunction with springs, they are always liable to become rickety, especially when worked on rough or paved roads. The rivets elongate and become loose, and ultimately the wheel goes to bits. To all intents and purposes only two varieties of wheels are generally used in the best modern practice. The most common has a heavy cast-iron rim, a cast-iron hub, and wrought-iron spokes, put in at some angle, or so bent that they provide a certain amount of elasticity. This is essential, not so much for the sake of the engine when running, because the tire being cast round the spokes, would, when contracting in cooling, certainly burst if the spokes were absolutely rigid. The great difficulty to be overcome lies in securing an intimate union between the wrought and cast iron. The ordinary plan is to fix the spokes in the floor of the foundry in position, and to cast the rim round them. When this has set and cooled down to about a red heat the boss or hub is cast. If the casting of the latter is delayed till the outer ring is quite cold it will be liable, if of large size, to draw away from the spokes fixed in the rigid tire. The great point is so to proportion the temperatures of the two portions of the wheel that the contraction may be equal throughout the whole; and this is very successfully accomplished in the present day, although the contrary was the fact a few years since. Three or four methods of making the cast iron unite with the wrought, or, at least, of permanently securing the one to the other, have been tried. The simplest is to split the ends of the spoke and open them out slightly for an inch or two; round spokes are notched like a lewis. Some makers punch one or two holes in each end of the spoke, which the fluid metal fills, forming a permanent pin or cottar. But none of these plans will alone suffice to prevent the spokes from becoming loose in time. To avoid this an intimate union—a partial welding or soldering, so to speak—must be established between the two metals. This can only be effected by running much more iron through the mould than is wanted, and so "burning" the spokes in, or else by coating the ends of the spokes with some flux which will answer the purpose of establishing a union, on the same principle that a tinsmith uses resin, or a gasfitter muriate of ammonia. There are various nostrums in favor for effecting this end. One is gas-tar, into which the ends of the spokes, well cleaned, are dipped before putting them in the mould. We have ourselves tried this, with very indifferent results, although others have been more successful. The best plan is to tin the end of the spoke. We cannot call to mind a single instance in which a tinned spoke became loose, if proper care was used to feed the casting with rods during the first twenty minutes or so after the metal was poured.

In whatever way a rigid wheel is made, it is essential to its success that its sur-

face must be roughened. A smooth wrought-iron tire possesses very litte bite to begin with, and after it has worn itself bright by slipping, it has practically no adhesion. A cast-iron tire is still worse; it is, therefore, the custom either to cast ridges across the tire or to fit it with strips of wrought iron about 4 in. wide and $\frac{3}{4}$ in. thick, disposed spirally across the rim, with vacant spaces between the strips. The spiral arrangement is intended to prevent the jolting which would otherwise take place as the vacant spaces and cross bars alternately came to the ground. In other respects the arrangement is prejudicial. The best possible way to make a rigid wheel hold well is shown in the annexed diagram, but the system is rather costly. We have here a nearly continuous



rib round the centre of the breadth of the wheel, but the moment any abrasion of the road from slipping occurs the bars get a good hold. Each strip is of soft wrought iron, fixed by two steel rivets, the snap heads of which—on the outside—are well developed, and conical instead of hemispherical. From such a wheel, about 7 ft. in diameter and 18 in. broad, the maximum adhesion of which a rigid wheel is capable may be had. The Thomson wheel, the second variety to which we have alluded, has so frequently been illustrated in these pages, that we need not again consider its peculiarities here; they must be familiar to our readers.

Having thus generally indicated the principles observed in the construction of traction engine wheels, we have next to consider the nature of the laws on which their adhesion, and, therefore, their relative efficiency depends. The subject has hardly yet been dealt with as it ought, and one or two letters which have appeared in "The Engineer" go to show that the subject is very imperfectly und rstood.

It is commonly assumed that the adhesion of the wheel of a traction engine is simply a function of static friction, and the well-known laws of friction not being found to apply, all manner of hypotheses are adopted to explain the apparent paradox. To put this in a plainer light, let us define the principal law of friction implicated. It is that the resistance—which in this case is synonymous with adhesion—is totally independent of the extent of the surfaces in contact, and directly proportional to the forces holding these surfaces together. Now it is perfectly well known that an elastic or Thomson tire possesses more adhesion than a rigid tire in the proportion of about 5 to 3 on good roads, and there are no means of explaining this fact except that the elastic tire extends the surface of contact. But it is objected that nothing is to be had from this extension, because adhesion is independent of surface; and therefore we have been furnished with more than one ingenious theory to explain what really is extremly simple, and should be quite obvious. It is quite true that friction is independent of surface, so long as the surfaces remain intact, but it ceases to be true the moment abrasion takes place. To illustrate our meaning, let us suppose a bar of lead to be cast 1 in. wide, 10 in long, and $\frac{1}{4}$ in. thick; let this be fixed in a vice with the broad side up, and let a coarse 15 in. flat file be laid on it lengthwise. A certain force will be required to impart longitudinal motion to the file held down on the lead with a specific weight. The particles of lead will be engaged with the teeth of the file, and before the latter can move, all the particles of lead so interlocked must be torn off the main body of the mass, and the total resistance will be found by multiplying the resistance of any one particle by the whole number of disrupted particles. If the file is loaded sufficiently to fill up all the cavities, no increase of load will practically, within certain limits, increase the resistance offered by the lead to the motion of the file. Now let us turn the bar of lead with the edge up, and laying the file *across* it, load it as before. The resistance to motion will obviously depend on the whole number of particles of lead engaged in the file teeth, and, as these cannot be more than one-tenth of the number previously engaged, if the file be

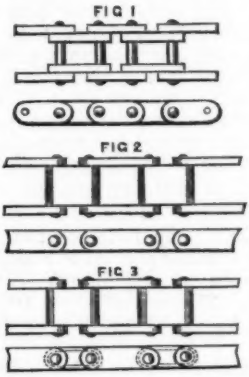
2 in. wide, it follows that the file can be moved across the bar of lead, under the conditions, with about one-tenth of the force required to move it along the bar. It must be clearly understood that in both cases the teeth of the file are filled up, and that no motion can take place without the abrasion of the lead over the whole surface covered by the file. Here, then, we find that the adhesion is absolutely dependent, under the conditions, on the extent of surface involved. Now, the case of a traction engine driving wheel is precisely analogous to that of our file and bar of lead—the wheel is the hard file, the road is the soft lead. If the lead were reduced in surface to a narrow edge it would offer no appreciable resistance to the file. If the bearing points of the driving wheels were reduced to a narrow line, say ¼ in. wide, across the rims of the wheels, the entire power developed by the engine must be resisted by the adhesion existing between the few particles of the road surface in contact with the wheel and those next below them. But there is no road in existence—not made of metal—which possesses sufficient internal cohesion to resist the strain to which it would be subjected. The upper crust would be at once torn off, and this would be succeeded by the next below, and so on until the wheel dug a pit for itself. But although two strips of road each ¼ in. wide, and 18 in. long, will not offer sufficient resistance to enable a traction engine to proceed, it is certain that they will offer *some* resistance to the rotation of the wheel, and this may be so multiplied by extension of surface that ample adhesion will be secured for all practical purposes. In this lies the advantages of the elastic wheel; it extends surface, and thereby enables a very weak and friable substance to resist a very considerable strain. Two or three Lilliputians could not have tied down Gulliver, but he must have succumbed to an army of Lilliputians. The elastic wheel simply permits us to call in the aid of an army of insignificant resistances, and to work the whole at once, whereas the rigid wheel takes them in detail and the road is beaten. Such are the general principles on which the efficiency of the elastic tire depends; we have yet to consider the action of the expedients used in connection with rigid wheels to obtain a similar result.

We had the pleasure of witnessing recently a series of experiments, which enables us to write this article in the light of the most recent information to be had on the subject.

About two years ago a committee, with Col. Galwey as president, was appointed by the Government to consider the advisability of adopting traction engines for military service. An engine, which has already been described in our pages as the "Steam Sapper," was specially constructed by Messrs. Aveling & Porter, of Rochester, for the Government, and underwent a series of exhaustive trials, with very satisfactory results, at the hands of the committee. The conclusion arrived at was that such engines might be found very serviceable indeed, but the engine was considered to be a little too heavy for the purposes of warfare. One of the principal duties proposed for such engines was the getting of siege guns or heavy artillery into position, and it was thought proper that the weight of the engine should not exceed that of the heaviest siege gun normal to battering trains. This *was* the 95 cwt. Armstrong breech-loader. What it will be no one at present is prepared, we believe, to say. With its carriage, the gun we have named weighs about 5 tons 13 cwt., or a little less; and it is necessary to keep down the weight of the engine to at least this point, in order that the permanence of pontoon bridges especially designed to carry the guns may not be endangered. If the guns are to be got into position at all, cases may arise in which the pontoons must carry them; but it would be very awkward, to say the least, if the propelling power weighed so much that it could not go where its load could, so that for general purposes traction engines to be used in warfare must weigh as much less than 5 tons 13 cwt. as possible. To meet this necessity, Messrs. Aveling & Porter have just constructed a second "Steam Sapper," which is, we feel certain, the lightest engine of the power yet constructed, and with this engine the trials were made.

In general construction the engine is very similar to the 6-horse power engine which attracted so much attention at the Wolverhampton Show, particulars of the experiments with which have been fully reported in our pages. The boiler is

of the locomotive type, containing 106 sq. ft. of heating surface. The single cylinder is $7\frac{3}{4}$ in. diameter and 10 in. stroke. The principal difference is in the size of the tank, which holds about 78 gallons instead of 120 gallons. In all cases where strength is merely a question of dimensions these last remain unchanged. By the rigorous exclusion of every superfluous morsel of material, however, a very important reduction of weight has been effected, the new engine weighing on the Government machine in Chatham Dockyard only 4 tons 15 cwt. 3 qr. with steam up, over 1 cwt. of coal in the furnace, and 50 gallons of water in the tank. Of this weight the driving wheels carry 3 tons 14 cwt. 3 qr. In the present article we have more to do with the construction of the driving wheels of this engine than with anything else; but, as will be seen in a moment, its remarkable efficiency strongly corroborates all that has ever been advanced in these pages in favor of light and simple engines. To return, however, to the driving-wheels —these possess some peculiarities worth attention. They are all of wrought iron except the bosses, which are of cast iron, into which flat wrought-iron spokes, crossing each other, and fitted with T heads at the outer end, are cast. Before the tire is put on, the spoke ends are all turned off to the same circle, so that they abut accurately against the inside of the tire, which is of wrought iron 10 in. wide and about $\frac{4}{8}$ in. thick, stiffened by two angle iron rings, to which the spokes are fixed by two rivets in each end, in a way well understood. The weight of the engine is not supported by the rivets, but by the ends of the spokes. The tire is fitted outside with wrought iron spiral strips $2\frac{1}{2}$ in. wide by 7 in. long and about $\frac{1}{2}$ in. thick; each is secured by two good rivets with the snapheads outside. It is clear that most hard roads are convex, and it follows that the inside edges of the tires take most of the weight. In order to avoid all jolting, and to stiffen the wheels, Mr. Aveling has introduced at the inner edges in this engine a set of intermediate pieces of iron, put between the spiral strips, and secured each by one rivet. The arrangement will be understood in a moment by looking at the annexed sketch. The entire wheel is extremely light and very well made. At 9.30 A. M. a train, consisting of three wagons loaded with iron and one lorry with two heavy castings, was brought to the foot of Star Hill, Rochester, by another



and heavier engine, and left there for the new engine, which, after a few moments delay, was coupled to the train and proceeded to ascend the hill in the presence of Colonel Wray and the Secretary of the Committee, Captain Clayton. The gradients of Star Hill are exceptionally severe (varying from 1 in. 75 to 1 in. 10); the surface was dry, in some places dusty, for the most part very hard, and in all affording indifferent bite. The net weight of the train was, according to the Rochester weighbridge, 15 tons 6 cwt. 2 qr. 14 lbs., made up thus:—First wagon, 4 tons; second wagon, 4 tons 10 cwt. 2 qr. 14 lbs.; third wagon, 4 tons 8 cwt.; lorry 2 tons 8 cwt. The whole train was weighed in Chatham Dockyard afterwards, with the following results: First wagon 3 tons 19 cwt.; second wagon, 4 tons 11 cwt. 3 qr.; third wagon, 4 tons 6 cwt. 1 qr.; lorry, 2 tons 6 cwt. 3 qr. 14 lbs.; total, 15 tons 3 cwt. 3 qr. 14 lbs. The disparity is due partly to the fact that the leading wagon carried a tank of water for the supply of the engine, some of which was used on the road; secondly, to the fact that some chains were transferred from one wagon to another; and lastly to the inefficiency of the Chatham Government weighbridge, which, although nominally up to 10 tons, is, we were told by the officials, unreliable when more than 3 tons are put on it. We have been thus particular, because in recording experiments on adhesion it is to the last degree important that the weights should be accurately stated. We may add

here that the inclines given were taken by the Government authorities, and are therefore reliable. The gross load, including the engine, taken up Star Hill was, by the Rochester weighbridge, and neglecting pounds, 20 tons 2 cwt. 1 qr.; by the Chatham bridge it was 19 tons 19 cwt. 2 qr. We shall for convenience assume it to have been in round numbers 20 tons, or 44,800 lbs. With this load the engine just got up without any slipping of consequence, but it is probable that on the steepest part of the hill she was loaded to the last ounce. There was a slight slip the whole way up, but except on one very dusty and rather soft bit of road, want of adhesion in no way interfered with her progress. Steam rose from 105., lbs. at starting to about 120 lbs. at the top of the hill.

The chances are, we think, about 100 to 1 that this performance is at present unparalleled. The inclines dealt with, it will be seen, vary in steepness between 1 in 22 and 1 in 11. The surface of the road was so good and hard that the resistance due to rolling friction could not well have exceeded 30 lbs. per ton, or 600 lbs. for the whole train. The resistance due to gravity, with the gross resistance for each of the gradients, is shown in the annexed table :—

Gradient.	Resistance due to gravity only.	Gross resistance, including rolling friction.
	lbs.	lbs.
1 in 22	2037	2637
1 in 16	2800	3400
1 in 14	3200	3800
1 in 11	4072	4674

In estimating the load on the driving wheels we must bear in mind that, on the one hand, the engine lost weight by standing on the inclines—to the extent on the gradient of 1 in 11 of 8.63 cwt.—but, on the other hand, the water was thrown further back, and the distribution was affected by the draught of the engine. We may assume, therefore, without much fear of error, that the load on the driving wheels going up the hill was the same as on the weighbridge. A very simple calculation then suffices to show that the engine took 5.3 times the load on the drivers up 1 in 11. There can be no dispute about this, as it was done, not only in our presence, but in that of the members of the committee. If follows, therefore, that the adhesion of the wheels we have described must have amounted on the road in question to 54 per cent. of the insistant weight.

It is beside our purpose to detail here the further trials as to handiness to which the engine was subjected. It must suffice to say that all that was expected she performed. Proceeding on her way to the dockyard, a new phase of the rigid tire system, and one which is extremely instructive, manifested itself. On the road from the railway station of the London, Chatham, and Dover line, and near the barracks, is a small bridge, pitched with ordinary paving sets, and nearly level. The road is rather worn, however, close to the part where the pavement begins, and wheels passing it have to make a of species jump ; still, it does not amount to much in the use of a train, because the wheels take it one after other, and the maximum resistance due to the jump is measured by the resistance offered to one pair of wheels. Over this bridge, however, the engine obstinately refused to take her load. On these paving sets the adhesion appeared to be reduced to about one-sixth of what it was on Star Hill. Chaining, and all kinds of devices were tried, and in the end it was with very great difficulty and after much loss of time that the engine succeeded in taking the first two wagons, weighing 8 tons 10 cwt. 2 qr., over. Once past, the pitching adhesion was restored, and engine and train proceeded up hill to the barracks, and then turned sharply up what is known as Brompton Hill, the steepest bit of which is 1 in 10. The road here is very hard and stony, and from lack of adhesion the utmost the engine could accomplish consisted in taking up the two leading wagons ; a second engine in attendance following with the other two. The train was afterwards coupled up, and proceeded without further hitch or difficulty to the weighbridge in Chatham Dockyard, returning in the afternoon to Messrs. Aveling & Porter's Works in Rochester.

We in our last impression explained that what is called adhesion in road locomotives simply consists in an interlocking of the surfaces in contact. This interlocking may be of two kinds. The asperities of the road and those of the tire may be

very small and numerous, or they may be few and large; the results obtained may, nevertheless, be the same in both cases. Again, the road may be very much harder than the tire, in which case the asperities of the former will sink into the latter; or the tire may be much harder than the road, in which case the latter will be indented instead of the former. But here again the results will be nearly the same.

Let us now compare the rigid with the elastic wheel in the light of the experiments we have just recorded. The rigid wheel is able to advance solely on the strength of its roughness. The wheels we have illustrated were nearly new and the snap heads of the rivets were sharp and well developed. They dug themselves into the hard surface of Star Hill with great energy and effect. The edges of the cross strips helped, no doubt, but a glance at the track left by the engine would suffice to convince any dispassionate observer that it was the claw-like action of the rivets that enabled the engine to ascend the various gradients passed over, on precisely the same principle that a cat climbs a tree; adhesion, in the sense ordinarily used, there was none. The damage done to the road was infinitesimal; a single horse going up with half a ton of coals in a cart would do more. In this case the road, hard as it was, was softer than the tire, and the asperities (rivets) on the latter sunk into the yielding surface. If the road had been a little softer the cross-strips would have sunk in as well as the rivets, and an additional bite would have been obtained. If, on the other hand, a Thomson tire had been used, the asperities of the road would have sunk into the tire, and the adhesion would possibly have been just as great with india-rubber as with soft iron, though the mode of action of the two would have been essentially different.

The question remains to be considered, which is the best material for a traction engine tire—india-rubber or iron? If we take the great cost of india-rubber tires—amounting as it does, to £200 for a pair of 6 ft. tires, 14 in. wide—into account, then it is indisputable the iron is the best. If, however, we handle this question in a purely mechanical way, and neglect all considerations of cost, it will be seen that on the whole, the india-rubber tire is the best, for the following reasons:—We have pointed out that without a mutual interlocking of the road and the tire there can be no adhesion. The rigid tire is designed on the presumption that the road will always be softer than the tire, and this proposition is generally true; it is, however, impossible to secure that it shall invariably be true. But when a rigid tire meets with a bit of road equally hard, adhesion becomes evanescent. The tire cannot bite the road, the road cannot bite the tire. The engine fails to proceed precisely in the same way that a cat fails to climb a polished iron pillar; and for this reason the "Steam Sapper No. 2" failed, as we have explained, to take her load across the paved bridge. It may be urged that such bits of road are exceptional; but granting this—although it is not quite true—the balance of advantage is still in favor of india-rubber, because as the strength of a chain is only that of the weakest link, so a traction engine might totally fail to accomplish the purpose for which it was intended if 100 yards of paved road were encountered in a run of 100 miles. It is impossible to secure the invariable presence of a road softer than the tire; but it is possible to secure the presence of a tire which shall be more yielding than any highway in existence by the use of india-rubber; and it, therefore, appears to be on the whole better that the road should indent itself into the tire than that the tire should indent itself into the road.

But the question cannot be settled on this basis alone; there is another point to be considered. The rigid wheel depends for the manifestation of great powers of traction solely on the roughness of its surface. Therefore, a wheel which is just out of the maker's hands may do excellent work, and yet be rendered comparatively useless in a week. The chances are that, after a fortnight's continuous service, "Steam Sapper No. 2" will be utterly unable to get up Star Hill with more than ½ the load she took up on Tuesday. The rivets will be all worn down and the corners rounded off the cross-strips. It must not be forgotten, however, that at a very moderate outlay the original efficiency of the wheels can be restored by merely putting in new rivets. No such difficulty can arise with india-rubber tires. So long as a road exists it is certain to be rough, and if we carry the soft ma-

terial in the shape of india-rubber with us, all will go right. The drawback is the enormous cost of the rubber.

It is quite certain that nothing like the most has yet been made of rigid wheels. Builders of such engines may take a lesson from any maker of ploughshares in the art of producing wheels the asperities on which shall always be sharp and capable of biting the ground until the wheel is pretty nearly worn out. In the matter of rivets alone there is a great field for improvement. No one now thinks of fixing an eccentric with pointed set screws, sunk-ended screws being always used for the purpose, because if shifted ever so little, they take a fresh grip; but no one ever saw a sunk-ended rivet used in a traction-engine wheel. This, and a great many other things have to be learned before the rigid wheel is made all that it can be made; and, after all, it is possible that an elastic wheel, possessing its advantages and none of its disadvantages, may be produced at the price of the improved rigid wheel. Be this as it may, it is certain that each day is adding to the stock of information concerning traction engines; every experiment made with them is more encouraging than the last, and affords fairer and yet fairer promise of the attainment of an ultimate success greater than is now held to be possible, except by a very few, among whom we beg to include ourselves.

And here we bring our series of papers on the construction of traction engines to a conclusion, at least for the present. We have done, we know, little more than state a few of the general principles which should guide engineers in their design and construction. The literature of the subject is meagre to the last degree. We have written in the hope that our very moderate contribution to it may prove of service, especially to our younger readers. It still remains as much as ever our duty to record in our pages every improvement that may be effected in a most interesting, attractive, and important branch of mechanical engineering.

NESQUEHONING TUNNEL.

From "Transactions of American Society of Civil Engineers."

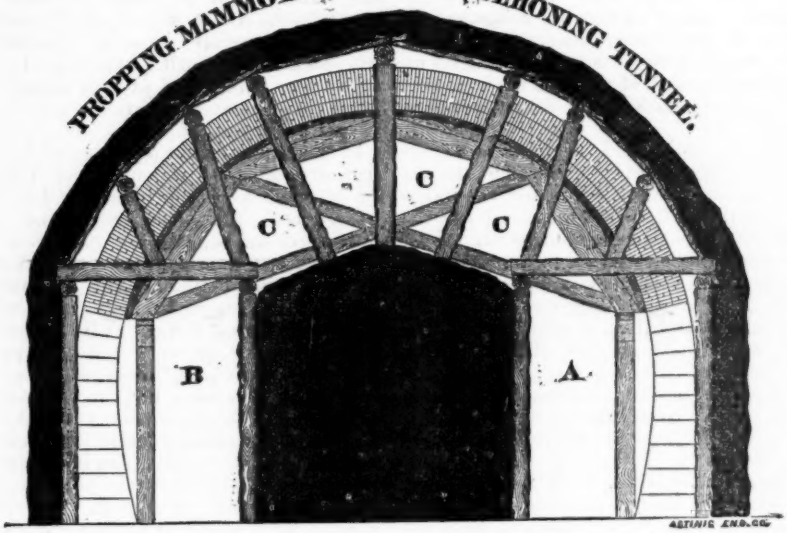
Nesquehoning Tunnel, in Carbon County, Pennsylvania, is a work of the Lehigh Coal and Navigation Company. It pierces Locust Mountain, and will connect their railroad in Nesquehoning Valley with their extensive coal operations in the valley of Panther Creek. At present this coal finds its way to market by that interesting system of inclined planes and gravity roads known as the "Switch-backs of Mauch Chunk," which has commanded the admiration of travellers for more than 40 years, not only on account of the beautiful scenery which the route displays, but also from its early and admirable adaptation to the purpose for which it was designed. It has, however, become worked up to its capacity, and in arranging to extend their coal mining operations, the Company have wisely determined to avail themselves of the locomotive, which has had its practical development since they were the pioneers in railway enterprise.

It passes through the base of the mountain at an elevation of some 15 ft. above the water on either side, and 554 ft. below the crest, and cuts the strata at right angles, where they have a south dip of about 45 deg. Its length in 3,800 ft., of which 1,300 ft. are through the coal-measures, with all their various strata of coal, coal-shale, sandstone, and conglomerate; 1,200 ft. through the conglomerate formation, with its occasional strata of coal-slates and sandstone; 1,000 ft. through the red shale, with occasional strata of sandstone, and 300 ft. at the north end through the debris, and soft and decomposed red shale which is found overlaying the red shale formation. It has encountered in its progress as hard and as soft material as is often met with in tunnelling.

After mature investigation it was determined to use the Burleigh Drills, driven by compressed air. With the advantage of the experience at Mont Cenis and Hoosac before us, we should, and it is believed we have obtained better results, as to cost and progress, than attended either of those works in their early stages, and I may here state that I believe no other known process is capable of pene-

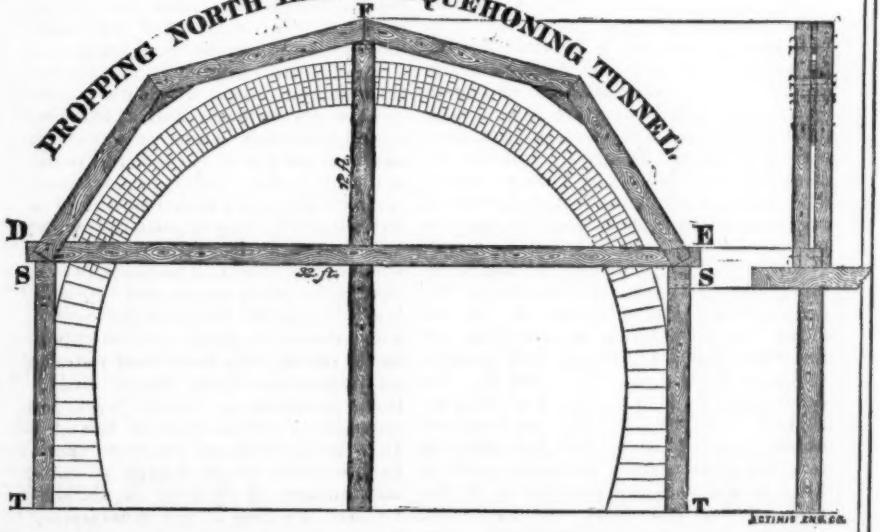
No. 1.

PROPPING MAMMOTH VEIN NESQUEHONING TUNNEL.



No. 2.

PROPPING NORTH END NESQUEHONING TUNNEL.



trating this conglomerate formation, with that economy and rapidity which is necessary to meet the present demands of capital. This whole work has been done with 6 of the "two-drill" compressors, made at Fitchburg, Mass., and with 16 drill engines, and we have averaged as much as one-half of the drill engines constantly in operation, and sometimes two-thirds.

The explosive used was gunpowder, ignited by the electric spark; but the requirements of ventilation, and the hardness of the rock, demanded powder of the highest Government standard. Some doubts which existed as to the economy in the use of the more powerful explosives, when the cost of drilling was reduced by machinery, and their greater danger, with the existing knowledge of workmen of their use, caused them to be rejected, and the result in the freedom from serious accident has been satisfactory, as we have not, thus far, lost a life from premature explosions.

American steel has been used; several of our own makers produce a better and cheaper article for the purpose than can be obtained from abroad, and the best we have had is from the William Butcher Steel Works at Philadelphia.

The headings are driven at the bottom, 8 ft. high by 16 ft. wide, and where arching is required, the full width for a double track is taken ont, that the tunnel may hereafter be enlarged, without disturbing the arches. At this date both headings are in the red shale, and about 500 ft. apart; they will be joined in August, and, until the tunnel is finished, full details of the work cannot be given; but the accompanying statement of Thos. C. Steele, chief assistant-engineer of the operations at the south end, up to June 1st, may be of some interest.

The heading to which the tabular statement refers, has been 12 months in the conglomerate, and 2 months in the red shale; the progress in the conglomerate has been about 100 ft. per full month's work, and in the red shale 160 ft. The holes drilled per cubic yard of rock removed, have been in the conglomerate about 11 ft., and in the red shale about 6½ ft. The powder used per cubic yard has been in the conglomerate about 6 lbs., and in the red shale about 3½ lbs., though a bad lot of powder ran the consumption in the conglomerate up to 7½ lbs. for two months.

The operation in the enlargement, to which the statement refers, has been 8 months in the coal measures, and 2 months in the conglomerate; its average monthly progress has been 166 ft.; its average holes drilled, per cubic yard of rock removed, $3\frac{3}{10}$ ft.; and its average powder used $2\frac{7}{10}$ lbs. per cubic yard.

In this enlargement a portion of hand-drilling is included, which extended over the operations of one month, and it increased both the holes drilled, and the powder consumed, showing that men do not use better judgment in directing hand than machine drilling. The Mammoth Coal Vein in this region is 50 ft. in thickness, and where it was cut by the tunnel, it was crushed, or to use a miner's expression, it was "in fault," and great care was necessary to prevent a "run," or to be more explicit, to prevent this crushed coal from running into the tunnel, its inclination being 45 deg. If a run had started, it would probably have extended to the outcrop, a height of 400 ft. The plan marked No. 1 will show the mode of propping. The galleries A and F, were first driven, and the masonry abutments built in them, after which the cutting over at C C C was done, leaving a core in the centre to prop upon, which being effected, the brick arch was turned, and the centre removed. The same plan was substantially followed in other coal veins.

The North Approach was excavated through the debris, which was about the same weight as water, and as there was a considerable flow of water into the cutting, and over the top of the soft red shale, its agitation in the process of excavation converted it into quicksand, and caused some trouble in its removal (with the slides and sinks usual in such cases), as well as in starting the tunnel. The depth of excavation at the north portal is 65 ft., and the lower half of the tunnel at that point is in soft red shale in place, and the upper half in the debris, with the flow of water referred to upon the top of the red shale. To those accustomed to such work, I need not relate the difficulties of the position. In order to effect an entrance there was first turned a strong façade of masonry, with an arch of 15 ft. in depth, abutting against the face of the excavation; the heading was then started upon the top of

soft red shale, 32 ft. in width and 12 ft. in height, an unusal size for a soft ground heading. The Plan No. 2 will indicate the mode of propping; plank shields were placed in the face of the heading, to prevents its running, and the frames D, E, F, wh plank lagging and fore poling, were put in at a distances of 3 to 4 ft. from centre to centre, resting at their base, D, E, upon the more solid red shale. This operation was continued a distance of 340 ft., and until solid rock was met, with the full depth of the tunnel. The next operation was to slip the sills S, S, by a careful process, under the base of the frames, to cut away for the props, S, T, and to put in the stone abutments and brick arches, packing them carefully on the top with the rock from the tunnel excavation. When the frost was leaving the ground last spring, the superincumbent mass came down with crushing effect upon the framing, but they resisted its influence, and have since been strengthened by the arches.

STATEMENT OF THE WORKINGS OF THE SOUTH END OF NESQUEHONING TUNNEL

Heading.

MONTH.	Feet of Holes Drilled.	Lbs. of Powder used.	Feet Progress.	Cubic Yards Progress.	Feet of Holes per Cubic Yard.	Lbs. Powder per Cubic Yard.
1870.						
April	2740	1125	73.	413.	6.6	2.7
May	6698	2725	138.	781.	8.6	3 5
June	6779	4200	104.	589.	11.5	7.1*
July	5862	4275	97.5	553.5	10.5	7.7*
August	5179	2750	82.	464.7	11.1	6.0
September	4920	2625	72.5	410.8	11.9	6.4
October	6052	2525	91.	520.	11.6	4 9
November	5054	2700	103 5	586 5	8 6	4.6
December	4638	2400	78.	442.	10.5	5.4
1871.						
January	5438	2900	101.	496.	11.0	5 8
February	6161	2825	93 5	530.	11.6	5.3
March	6043	3400	104.	589.5	10 2	5.8
April	6114	3000	157.	890.	6 8	3 4
May	5793	3600	164.	928.	6 3	3 9
Total	77471	41050	1459.	8'94.	9.4	5.0

* Bad Powder. Average, 104.

Enlargement.

MONTH.	Feet of Holes Drilled.	Lbs. of Powder used.	Feet Progress.	Cubic Yards Progress	Feet of Holes per Cubic Yard.	Lbs. Powder per Cubic Yard.
1870.						
August	2223	1450	125.	1000.9	2.2	1.4
September	2584	2125	123 5	905.7	2 9	2.3
October	3491	2650	153 5	1237.	2.8	2 1
November	4408	2700	120.	1276.5	3 4	2.1
December	4410	5775	156.	1002.	4.4	5.7*
1871.						
January	3667	3075	164 5	1158.	3 2	2.7
February	3432	3900	265.	1701.	2 0	2.3
March	5316	3990	215.5	1359.5	3.9	2.9
April	2633	1900	195 5	666.	4 0	2.9
May	4438	2600	145.5	873.	5.0	2.9
Total	36602	30075	1664.	11179 6	3.3	2.7

* Partly Hand Drilling. Average, 166.

Mr. F. C. Collingwood succeeded Mr. Steele, with some observations on the East River Bridge foundation.

RECENT RESEARCHES ON FLIGHT.

From the "English Mechanic and World of Science."

Mr. J. Murie has an article on this subject in a recent number of "Land and Water." Of late, says the author, the perplexing problem of flight has received a greater amount of attention from physiologists and savants than has been bestowed upon it for years, and the result of their researches and experiences is in a fair way of becoming remarkable for its fruit-bearing character. Whilst abroad, such men as Borelli, Straus-Durckheim, Charier, Girard,and Marey, have severally given to the world the gist of their labors in this branch of science; at home, the Duke of Argyll and Dr. J. Bell Pettigrew have awakened our deep interest by their views on natural and artificial flight. To the latter is due the honor of giving birth to the celebrated "figure-of-8 wave theory," that is now attracting so much notice in our aeronautical schools

As early as 1867, Dr. Pettigrew delivered, before the Royal Institution of Great Britain, a lecture in which he propounded that novel theory, and in 1868 he published in the "Transactions" of the Linnean Society an elaborate memoir on "The Mechanical Appliances by which Flight is Attained in the Animal Kingdom." The year after, Professor J. E. Marey, in the "Revue des Cours Scientifiques," bore out Dr. Pettigrew's ideas, by the detail of his experiments with the sphygmograph, with which he succeeded in causing the wings of insects and birds to register their own movements. He says: "But if the frequency of the movements of the wing vary, the form does not vary. It is invariably the same; it is always a double loop, a figure of 8. Whether this figure be more or less apparent; whether its branches be more or less equal, matters little; it exists, and an attentive examination will not fail to reveal it." An indefatigable worker, Dr. Pettigrew continued, without pausing, the task to which he had set himself—and that to him is indeed a labor of love; and in this year's "Transactions of the Royal Society of Edinburgh," we have from his pen a complete monograph on "The Physiology of Wings," in which he treats with equal felicity of both natural and artificial flight. The mass of interesting facts brought to light by the author is too copious to allow of lengthened discussion, but from it we abstract the following items:—

The wing is generally triangular in form. It is finely graduated, and tapers from the root towards the tip. It is likewise slightly twisted upon itself, and this remark holds true also of the primary or rowing feathers of the wing of the bird. The wing is convex above and concave below; this shape, and the fact that in flight the wing is carried obliquely forward like a kite, enabling it to penetrate the air with its dorsal surface during the up stroke, and to seize it with its ventral one alike during the down and up strokes. The wing is movable in all its parts; it is also elastic. Its power of changing form enables it to be wielded intelligently, even to its extremity; its elasticity prevents shock, and contributes to its continued play. The wing of the insect is usually in one piece, that of the bat and bird always in several. The curtain of the wing is continuous in the bat, because of a delicate elastic membrane which extends between the fingers of the hand and along the arm; that of the bird is non-continuous, owing to the presence of feathers, which open and close like so many valves during the up and down strokes.

The posterior margin of the wing of the insect, bat, and bird is rotated downwards and forwards during extension, and upwards and backwards during flexion. The wing during its vibration descends further below the body than it rises above it. This is necessary for elevating purposes. The distal portion of the wing is twisted in a downward and forward direction at the end of the down stroke, whereas at the end of the up stroke it is twisted downwards and backwards. The wing during its vibrations twists and untwists, so that it acts as a reversing reciprocating screw. The wing is consequently a screw, structurally and functionally. The blur or impression produced on the eye by the rapidly oscillating wing is twisted upon itself, and resembles the blade of an ordinary screw-propeller. The twisted configuration of the wing and its screwing action are due to the presence of figure-of-

8 looped curves on its anterior and posterior margins; these curves, when the wing is vibrating, reversing and reciprocating in such a manner as to make the wing change form in all its parts.

We may further point out that Dr. Pettigrew has not based his ideas on the structure of wings on mere theoretical considerations. Besides elaborate anatomical examination, he has entered with a true experimental spirit into a close study of the visible movements of most of the winged tribe. The very excellent diagramatic views with which his paper is elaborately illustrated, convey at a glance much that is difficut to express in words. In proof of this, the reader need but compare those figures bearing on the wing movements of the butterfly, the dragonfly, and the bird.

On these and similar deductions from the practical study of natural history, Dr. Pettigrew bases his elements of artificial flight. These are in themselves so interesting and new that we must defer a notice of them to another occasion.

STRENGTH OF GIRDERS TESTED BY MODELS.

By KOPKA.

Translated from "Der Civil Ingenieur."

On account of the uncertainty of the coefficients of strength and their variation, due to different conditions of temperature and moisture, to repeated bendings, shocks and vibrations, the theoretic determination of the dimensions of girders is not always to be relied on; so that it is desirable to test proof-strength and durability by means of a model.

The measurements of the tensions and pressures in the verticals and diagonals of the model of a bow-string girder, by means of the sound of a stretched wire—made by Airy, some years since, are very suggestive, both at first glance and upon closer examination.

It is not to be denied that a model which, with proportional load, shows strains proportional to those of a large girder is of much use, and that questions not answerable by calculation may find solution in it. But the construction of such models is attended with great difficulties, and, instead of dispensing with the theory of girders, requires a still more refined development.

It is matter of regret that in the account of Airy's experiments there is no proof that his model showed strains derivable from or equal to the corresponding depressions, stretchings and compressions in the actual bow-string girder. Suppose this proof supplied; then there should be experiments with greater span, and corrections should be made of the calculated results for the bow-string girder and for trusses subject only to tension and compression; the effect of small strains, as upon nuts, being neglected.

Calculation gives us no means for determining the effect of slight bendings continued during 100 years' use of the girder; while a model showing corresponding strains at corresponding points might solve the problem; if by means of some simple mechanism it were subjected to the same number of depressions in the course of a few weeks. In like manner, the resistance of girders under shocks and changes of temperature might be determined.

Airy's plan is therefore not to be rejected; but great pains must be taken that the model corresponds in development of strains with the projected girder. Otherwise great errors may be made, as will appear. But the laws of construction of such models are not simple; and the writer, in investigating them in the case of ordinary trusses, found such difficulty that he determined to examine the cases of the simplest girders.

For this kind of girder the model must be adjusted so that all sections are $\frac{1}{n}$th of the natural magnitude, and dimensions in length are $\frac{1}{\sqrt{n}}$th of the original; so that two standard measures are employed.

Measuring the proof-load not by pounds, but by the weight g of the model, and the projected load of the girder by its proper

weight G, we find that in model and girder for equal load-numbers at corresponding points there occur equal tensions and equal depressions; and the breaking point in model and girder occurs at the same place.

The same holds, if measuring all loads by g and G, the model were constructed according to the following standards, which, however, are useless in actual practice:—for the profile breadth, $\frac{1}{n}$th of natural size; for profile depth, $\frac{1}{n^2}$; and for length, $\frac{1}{n}$th. The above principle, then, is strictly expressed as follows: "A model with depth measure in the ratio of the square of the length and of the breadth measures, and which—its own weight being taken as the unit of weight—is loaded just like the girder, shows at corresponding points the same tension of fibre; and the depressions of model and girder are equal."

The investigation for framed and for free girders with any load is easily made, by representing model-numbers by small figures, and girder numbers by large; distinguishing again the latter from the former by use of the coefficient n.

Hence the proper weight of girder

$$G = gn^2\sqrt{n}$$

the length

$$L = l\sqrt{n}$$

the moment of resistance of symmetric or unsymmetric section

$$W = wn^3$$

the abscissa

$$X = x\sqrt{n}$$

If q_1, q_2, q_3, &c., represent the distributed loads in pounds, the fractions

$$\frac{q_1}{g}, \frac{q_2}{g}, \frac{q_3}{g}, \text{ \&c.,}$$

are used for the model; and

$$\frac{Q_1}{G}, \frac{Q_2}{G}, \frac{Q_3}{G}$$

for the girder; writing, instead of the fractions, z_1, z_2, z_3, &c., and Z_1, Z_2, Z_3.

Now, if the girder is to bear at a certain point Z times the weight G, the model must be loaded with Z times the weight of g; and hence we always have

$$\frac{q_1}{g} = Z_1 = \frac{Q_1}{G} = Z_1$$

or

$$\frac{q_2}{g} = z_2 = \frac{Q_2}{G} = z_2, \text{ \&c.}$$

Tension of Fibre.

Let σ = the tension of the external fibre;

w = the moment of resistance $= \frac{r}{e}$;

g = the weight of model;

then for free and also for framed beams we have

$$m_x = ax - \left(\frac{\alpha x_q}{2l} + m_1 + m_2 + \ldots + m_0\right) = \sigma w,$$

x being the abscissa of a point n, Fig. 1, $m_1 + m_2 +$, etc., being the load moment about n as centre, and m_0 the moment of the abutment or point of support. For free abutment this last moment is zero.

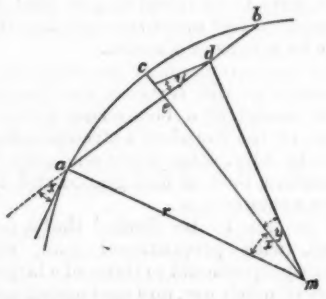
Hence the tension of the external fibre at a point whose abscissa is x is on the model

$$\sigma = \frac{1}{w}\left[ax - \left(\frac{qx^2}{2l} + m_1 + m_2 \ldots m_0\right)\right], \quad 1)$$

in the girder

$$\Sigma = \frac{1}{W}\left[AX - \left(\frac{GX^2}{2L} + M_1 + M_2 + \ldots M_0\right)\right]. \quad 2)$$

Fig. 1.



Comparing moments, we have for any moment in the model m_v

$$m_v = q_v (x - l_v)$$

or if

$$\frac{q_v}{g} = z_v$$

$$m_v = z_v (x - l_v) g.$$

and in the girder

$$M_v = Z_v (X - L_v) G, \text{ or since } Z_v = z_v$$

$$= z_v (x - l_v) g n^3,$$

or

$$M_v = m_v n^3. \quad \ldots \quad 3)$$

Hence

$$\frac{G X^2}{2L} = \frac{g x^2}{2l} \cdot n^3. \quad \ldots \quad 4)$$

Representing by m and M the moments of single loads referred to the other bearing point we have generally, in the model,

$$a = \frac{m_0 + m_1 + m_2 + \ldots + g\frac{l}{z}}{\mathrm{L}}$$

in the beam,

$$\mathrm{A} = \frac{\mathrm{M}_0 + \mathrm{M}_\Phi + \mathrm{M}_z + \ldots + \mathrm{G}\frac{\mathrm{L}}{z}}{\mathrm{L}}$$

or from (3) and (4) $\mathrm{A} = a\,n^2\sqrt{n}$.
Substituting from (3) (4) (5) in (2) the tension in the abscissa X,

$$\Sigma = \frac{n^3}{\mathrm{W}}\left[ax - \left(\frac{gx^2}{2l} + m_1 + m_2 + \ldots m_0\right)\right]$$

or, since for symmetric and unsymmetric section $\mathrm{W} = w\,n_3$,

$$\Sigma = \frac{1}{w}\left[ax - \left(\frac{gx^2}{2l} + m_1 + m_2 + \ldots m_0\right)\right]$$

that is, with reference to equation (1), is just as great as in the model.

From the equality of the external fibre-tension for corresponding profile, there follows, according to known laws, the equality of the fibre-tension for every corresponding point of the profile; and hence the point of rupture, or the place where the tension of the external fibre is at its maximum, must lie as in corresponding points of the model.

Deflection.

Let t = the moment of inertia
y = the deflection corresponding to the abscissa x
$q_1, q_2, \ldots$ = the distributed loads in pounds,
then the equation of the elastic line is

$$t\,\mathrm{E}\,\frac{d^2y}{ax^2} = m_x$$

or expanding,

$$t\,\mathrm{E}\,\frac{d^2y}{dx^2} = ax - m_0 - q_1(x - l_1) - q_2(x - l_2) \ldots . - \frac{gx^2}{2l}.$$

Integrating;

$$t\,\mathrm{E}\,\frac{dy}{ax} = \frac{ax^2}{2} - m_0 x - q_1\left(\frac{x^2}{2} - l_1 x\right) - q_2\left(\frac{x_2}{2} - l_2 x\right) \ldots . - \frac{g x^3}{6l} + c$$

and

$$t\,\mathrm{E}\,y = \frac{ax^3}{6} - m_0\frac{x^2}{2} - q_1\left(\frac{x^3}{6} - l_1\frac{x^2}{2}\right) - q_2\left(\frac{x^3}{6} - l_2\frac{x^2}{2}\right) \ldots - \frac{gx^4}{24l} + cx + c_1.$$

Let q = weight of model; then since $z = \frac{q}{g}$

$$t\,\mathrm{E}\,\frac{dy}{dx} = \frac{ax^2}{2} - m_0 x - z_1 g\left(\frac{x_2}{2} - l_1 x\right) - z_2 g\left(\frac{x^2}{2} - l_2 x\right) \ldots - \frac{gx^3}{6l} + c \quad \ldots \quad 1)$$

$$t\,\mathrm{E}\,y = \frac{ax}{b} - \mathrm{M}_0\frac{x^2}{2} - z_1 g\left(\frac{x^3}{6} - l_2\frac{x^2}{2}\right) - z_2 g\left(\frac{x^3}{6} - l_2\frac{x^2}{2}\right) \ldots - \frac{gx^4}{24l} + cx + c_1 \ldots 2)$$

For the girder; substitute large letters.

$$\mathrm{TE}\,\frac{d\mathrm{Y}}{d\mathrm{X}} = \frac{\mathrm{AX}^2}{2} - \mathrm{M}_0\mathrm{X} - \text{etc.} + \mathrm{C}. \quad 3)$$

$$\mathrm{TEY} = \frac{\mathrm{AX}^3}{6} - \mathrm{M}_0\frac{\mathrm{X}^2}{2} - \text{etc.} + \mathrm{CX} + \mathrm{C}_1. \quad 4)$$

Putting instead of (1)

$$t\,\mathrm{E}\,\frac{dy}{dx} = \mathrm{F}_x + c$$

and for (3) $\mathrm{TE}\,\frac{d\mathrm{Y}}{d\mathrm{X}} = \mathrm{F}_\mathrm{X} + \mathrm{C}$

and changing x_1, y_1, into X_1, and Y_1, the co-ordinates of the point of greatest depression, we have

$$\frac{dy}{dx} = \frac{d\mathrm{Y}}{d\mathrm{X}} = o$$

and hence, for model

$$(\mathrm{F}_x)^{x=x_1} = -c, \quad \ldots \quad 5)$$

for girder,

$$(\mathrm{F}_x)^{\mathrm{X}=\mathrm{X}_1} = -\mathrm{C}. \quad \ldots \quad 6)$$

But from (3), (4) and (5)

$$\frac{\mathrm{A}\,\mathrm{X}_1^2}{2} = a x_1^2\, n^3\sqrt{n}$$

$$\mathrm{M}_0\,\mathrm{X}_1 = m_0\, x_1^2\, n^3\sqrt{n}$$

$$\mathrm{Z}_1\,\mathrm{G}\left(\frac{\mathrm{X}_1^2}{2}\mathrm{L}_1\mathrm{X}_1\right) = n^3\sqrt{n}\,.\,z_1 g\left(\frac{x_1^2}{2} - l_1 x_1\right)$$

$$\ldots\ldots = n^3\sqrt{n}\ldots\ldots$$

$$\ldots\ldots = n^3\sqrt{n}\ldots\ldots$$

and finally

$$\frac{\mathrm{G}\,\mathrm{X}_1^3}{6\,\mathrm{L}} = n^3\sqrt{n}\,.\,\frac{g x_1^3}{6l}.$$

Substituting in (3) and comparing with (1)

$$\mathrm{F}_{\mathrm{X}1} = n^3\sqrt{n}\,.\,\mathrm{F}_{x1}$$

and from (5) and (6)

$$\mathrm{C} = cn^3\sqrt{n}. \quad \ldots \quad 7)$$

Instead of (2) and (4) put

$$t\,\mathrm{E}\,y = \phi_x + c_1$$

$$\mathrm{TEY} = \Phi_\mathrm{X} + \mathrm{C}_1,$$

then for

$$x = l \text{ and } \mathrm{X} = \mathrm{L},\ y = \mathrm{Y} = 0$$

and for model

$$(\phi_x)^{x=l} = -c_1. \quad 8)$$

for girder

$$(\Phi_X)^{X=L} = -C_1 \quad 9)$$

From (3), (4), (5) and (7) we have

$$\frac{A X_L^3}{6} = \frac{a x_i^3}{6} \cdot n^4 \qquad \frac{M_0 X_L^2}{2} = \frac{m_0 x_i^2}{2} \quad n^4$$

$$Z_1 G \left(\frac{X_L^3}{6} - \frac{L_1 X_L^2}{2} = z_1 g \left(\frac{x_i^3}{6} - \frac{l_1 x_i^2}{2} \right) n^4 \right.$$

$$\ldots\ldots = \ldots\ldots n^4$$

$$\ldots\ldots = \ldots\ldots n^4$$

$$\frac{G X_L^4}{24 L} = \frac{g x_i}{24 l} \cdot n^4$$

$$C X_L = c x_i \cdot n^4.$$

Substituting in (4) and comparing with (2)

$$\Phi_{XL} = n^4 \phi_{xl}$$

and $$C_1 = c^1 n^4 \ldots\ldots 10)$$

If $Z_1 = z^1$, &c., is the general equation.

$$TEY = \frac{AX^3}{6} - \frac{M_0 X_2}{2} z_1 G \left(\frac{X^3}{6} - L_1 \frac{X_2}{2} \right) \ldots$$

$$- \frac{GX^4}{24 L} + CX + C_1.$$

For symmetric and unsymmetric sections $T = tn^4$ and

$$A = an^2\sqrt{n} \qquad G = gn^2\sqrt{n}$$

$$X = x\sqrt{n} \qquad C = cn^3\sqrt{n}$$

$$M = m_0 n^3 \qquad C_1 = c_1 n_4$$

$$L_1 \text{ etc.} = l_1\sqrt{n}, \text{ etc.}$$

Substituting these values in Eq. 11 for the beam, and comparing the result with Eq. 2 for the model, we have for the depression for the abscissa X, $Y = y$; that is, just as great as in the model at the corresponding point.

IRON AND STEEL NOTES.

FINISHING STEEL.—Of all the methods or processes of working and finishing steel, probably there is none extensively used about which there is so little known by mechanics in general as that of the "friction-wheel," and this lack of knowledge has no doubt kept its use confined within the bounds of almost a single class of work. It is generally known that the smooth edge of a soft steel or iron wheel, when run at a high speed, will cut tempered steel, soft steel, iron, and other substances very rapidly, but with it goes the belief that steel so cut is practically ruined for all useful purposes. This is true only to a certain extent, and is entirely avoidable by a proper speed of the friction wheel and a skilful operator. A smooth steel wheel running with a periphery speed of from two to three miles per minute, will cut steel at a rapid rate, and without heating it to such an extent as to even change the color; the cutting wheel, too, retaining its form for a great length of time without being returned. Not only the spiral sides of augers and auger bits are smoothed out and finished by friction-wheels, but the fine screw points of the same are wholly formed by the sharp edge of a soft steel plate run at the frightful speed of 14,000 revolutions a minute. The freedom from heating or burning the work, as well as the accuracy and beauty with which it is done, is unquestionably in a great measure due to the skill of the operator; still this skill may be matched by the skill of the inventor, and the friction wheel applied to hundreds of purposes yet unthought of.—*Mechanics' Magazine.*

WIRE ROPE MANUFACTURE.—The wire rope works of Messrs. John A. Roebling's Sons, at Trenton, New Jersey, are the largest in the United States, occupying an area of 10 acres, located on the Delaware and Raritan Canal, and connected with the Camden and Amboy Railway. Bright wire, steel, and galvanized wire rope, in all sizes and length, are made, and the machinery is capable of making as large wire rope as can be manufactured. One piece, 5,870 ft. long, weighing 62,000 lbs., was recently made for the Lehigh and Susquehanna Railway, costing $10,540. The business was first started in 1849 by the late Mr. John A. Roebling, and now employs 125 hands, and 3 engines, giving in all 350-horse power. A rolling mill, in connection with the works, has a capacity for 40 tons of wire per week. A new building, to be 200 by 40, is now being built for a galvanizing house. The class of work turned out at this establishment is second to none in the world, as the results at the Niagara Falls and other suspension bridges fully prove. This wire will be used in the great East River Bridge now being constructed by the Messrs. Roebling.—*American Railway Times.*

IRON MAKING IN WISCONSIN.—Mr. Greeley, in some brief notes on Wisconsin, furnished the "Tribune," says great discoveries of iron ore have recently been made, mainly in the great wilderness stretching eastward from the Menominee, and several blast furnaces have been erected, mainly on or near Green Bay, though by far the largest is located at Milwaukee. As yet, those in the northern counties use Lake Superior ore costing 7 per ton, and melt it with charcoal costing 9 cents per bushel, making each ton of metal cost $28; and since its price in Chicago is but $33, the profit is small; but cheaper ores will doubtless be found and used, insuring a cheaper product and perhaps larger profits.—*American Railway Times.*

THE New Jersey Steel and Iron Company ranks among the largest establishments of the kind in the United States, and for the present is the largest manufacturing company in Trenton, N. J., employing 550 men. This is an incorporated company, and their property and machinery is valued at $750,000. Rolled wrought iron beams and bars, and iron and steel-headed rails, merchant iron and the Martin steel are among the products of this mill. The works occupy 12 acres, and are very extensive. The annual capacity of the mill is for 20,000 tons of rails, of 10,000 tons of beams, for flooring, bridges, etc. The flooring beams for the New York City Post Office are furnishd by this company. They have the exclusive control in the United States of the right to manufacture the Martin steel, under a French patent, and have one

furnace producing 5 tons at a charge. Their steel is used mostly for engine and machine work.—*American Railway Times.*

THE following table shows the average monthly and yearly prices of Anthracite Pig Iron No. 1, tons of 2,240 lbs., from 1860 inclusive to the present time; from weekly quotations in Philadelphia and New York prices current:

	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Year.
1860	23	23	23 15/16	22 3/4	22 3/4	22 3/4	22 3/4	22 1/4	22 1/4	22 3/4	22 3/4	22 1/4	22 3/4
1861	22 1/4	21 1/4	21 1/4	21 1/8	21 1/2	20 1/2	19 3/4	18 7/16	16 11/16	18 3/4	18 9/16	19 3/8	20 1/2
1862	20	20 3/4	20 1/4	21 1/4	21 1/2	22 3/4	24	24 3/8	24 1/4	25 1/4	30 1/4	31 1/2	23 3/8
1863	32	33 1/4	35 1/4	36	34 3/4	33 1/4	32 1/4	31 1/4	33	35 3/4	41 7/16	43 1/4	35 1/4
1864	43 9/16	49 3/8	50 1/8	54 1/4	57 1/4	57 3/8	69 1/16	73 3/8	72 1/4	69 3/4	61 1/4	59 1/16	59 1/4
1865	58 1/4	53 1/8	50 3/8	45 1/4	39 1/4	35	35 5/8	40 1/4	44 3/16	49 3/8	51	50 1/4	46 1/8
1866	50 3/4	49	46 7/16	41 1/4	41 3/8	43 3/16	46 1/4	47 1/8	47 7/8	48 1/4	49 1/4	49	46 7/16
1867	48 1/4	47 1/8	44 3/4	41	42 9/16	43	43 1/4	43 3/4	44 1/4	44 1/4	44	42	44 7/16
1868	37 5/8	36 3/4	37 1/4	38 1/8	37	36 5/8	38 1/4	39 3/16	40	41 1/4	42 1/2	43	39
1869	41 1/8	40 1/4	41 7/16	39 1/2	39 1/4	40 3/4	41 1/4	41	40 1/4	40 3/8	39 1/4	38 1/4	40 1/8
1870	36 1/4	34 3/4	34	32 3/4	32	32 1/8	32 1/4	33	32 3/4	31 3/8	30 3/4	30 1/8	32 7/16
1871	30 1/8	30 7/16	35 1/2	34 1/8	35	35 1/4	35 1/4	35 3/4	36 1/4	37			

AMERICAN PIG.—The future course of the Iron market is daily becoming a topic of great and increasing interest to very many of our readers. The winter supply of many of them must be bought and delivered soon, or they must either be short of metal or pay heavy railroad freights after the close of navigation. A brief recapitulation of the chief features of the market, as they appear to us, is therefore appropriate, and may aid some to arrive at a wise decision. In the first place, the genuine feeling among buyers of iron is that prices are too high, and must break very soon; producers, on the other hand, say that they are able not only to maintain present rates, but even to advance them, and $40 is freely spoken of as a probable price for No. 1 Foundry. The brokers generally take the view of the producers. In the beginning of this year American iron was lower than at any time since the price advanced from the ante-war rates, being quoted by us from January 12 to February 16 at $30 for Foundry No. 1. The coal strike, and consequent stoppage of most of the Anthracite furnaces, drained the market completely of iron, whether in the hands of producers, dealers or consumers; and since the resumption of coal mining and iron production, the price has steadily advanced until, to-day, the quotation is $37 to $38—and this price may be fairly called nominal, there is so little iron to be had. The furnace companies have none. A gentleman who went carefully through the Lehigh district last week saw only about a thousand tons of iron on the furnace banks, and the most of that would not have been there but for the difficulty of getting cars to take it away. Dealers and speculators have very little iron; and consumers, most of whom have ever since the advance been buying from hand to mouth, are very bare. Moreover, most of the furnace companies are largely oversold. The advance in price has been caused entirely by the short supply and a legitimate demand for consumption—the absence of speculation being one of its most marked features. If this demand for consumption continues, it seems to us inevitable that the price will be maintained, at least till after the close of navigation, and probably longer. Bearing on this point, we would remind our readers that the year 1870 began with large stocks in the hands of both furnace companies and consumers, which were very much reduced at the close of the year, showing that consumption was greater than production, notwithstanding the fall in price that occurred during the year. Then occurred the coal strike, which lessened the production of iron much more than its consumption; and since, business has been very active in all the trades that consume iron. Indeed, this is true of all metals used in staple manufactures, and prices of these metals have rapidly advanced. In fine, we think that iron ought to be purchased now by those who will need it soon. To our view, there is no sign of weakness in the market, and we inclide to the belief that, if nothing occurs to check the demand, there will not be the usual stocks of iron in the early months of next year. The advance in iron of all kinds has been as marked in Europe as in this country. —*Iron Age.*

SHEET-IRON stacks for heating and puddling furnaces are now being made in separate rings, instead of one whole length as formerly. Each ring has a band of flat bar-iron—horseshoe bar—about 2 in. from the lower edge, firmly riveted, and by which each is supported as it fits into and rests on the edge of the one next below. By making the stack in this way in short sections, it can be more conveniently erected, and also can be repaired by renewing any worn-out part or burnt

section at less cost, and much less labor, than when otherwise constructed.—*Am. Railway Times.*

RAILWAY IRON IN RUSSIA.—It is a noticeable fact that the demand for British railway iron in Russia, although still respectable, has greatly declined in importance this year. The shipments of our railway iron to Russia have been as follows, month by month, to August 31, in the last three years:—

Month.	1869.	1870.	1871.
	Tons.	Tons.	Tons.
January		908	193
February	1,283	65	2,951
March	7,145	3,133	5,856
April	21,166	20,619	5,782
May	23,120	52,741	19,466
June	34,072	36,988	12,731
July	35,731	26,094	7,610
August	36,532	23,152	11,095
Total	159,049	163,700	65,634

It is this flatness in the Russian demand, coupled with a decline in the consumption of our railway iron in British India, which, as has been before observed, has occasioned the comparative dulness in the British railway iron trade this year, a dulness which would have been still greater but for the progress of consumption in Canada and the United States. The principal cause of the decline in the Russian demand for our railway iron is probably to be found in the new clause introduced into the concessions of Russian lines, by which their administrations are required to purchase rails and plant to as large an extent as possible in Russia itself. The Czar's Government is doing all in its power to develop metallurgical industry upon the Russian soil, and the effect of this policy has been felt still more strongly by the Belgian than by the English iron trade. Thus, the exports of Belgian rails to Russia in the first six months of this year declined to the comparatively insignificant total of 580 tons.

Nevertheless, the railway interest has now acquired such importance in Russia, and the results obtained from working the lines thus far completed have been so encouraging—the burthen of the guarantees of interest given by the Russian Government having only involved a loss to the Russian Treasury in its last financial year of 9,000,000 roubles, instead of 26,000,000 roubles, as had been estimated—that, in spite of every effort which may be made to develop the production of iron in Russia, a good consumption of English rails in Russia seems probable for some years to come. The Russians appear to take more kindly to English railway *materiel* than to Belgian, financial considerations having possibly something to do with the matter. Thus the Russian Government and Russian guaranteed railway companies have borrowed, and will probably yet again borrow, largely in England; and where they raise capital they are not unlikely to give out orders, at any rate to some extent. Moreover, Russia is still very slenderly supplied with railways. In spite of the energetic efforts put forth during the last four or five years, Russia had still only 11,032 versts, or about 7,400 English miles, of railway in operation at the commencement of July, 1871. It is true that on the same date there were 3,276 versts, or about 2,165 English miles, in course of construction; but it is not very difficult to see that even when all the new lines now on hand are finished off, and even when Russia has 9,565 miles of iron-way in a condition to admit of the passage of trains, she will still have an immense deal to do before she will have fully satisfied her railway requirements. Russia has copied rather slavishly the example of England in the matter of railways. Her guarantee system is borrowed almost literally from British India, and one of the latest acts of the Russian Government has been the appointment of a commission to consider the desirability of constructing a system of light and very narrow gauge railways in the Caucasus. England has thus not only a financial, but a moral influence even in Russia. The Russians look with a certain respect and wistfulness still upon Great Britain, and they would fain penetrate some of the secrets which have enabled her to accumulate such enormous wealth, and to develop the mechanical arts with such remarkable success. So long as such a feeling as this remains in the Russian mind we shall still, we may depend upon it, enjoy a certain amount of Russian custom.

With a continuance of peace, Russian railways must grow year by year in importance and extent. There are two opposing influences at work in Russia—the commercial instinct and the military instinct. The progress of liberal ideas is felt, however, even in Russia. The Czar is still a mighty and almost irresponsible potentate, but even Russian Czars succumb to the genius of the age, and become penetrated with the ideas and influences of modern civilization. As year by year the immense material advantages resulting from railways impress themselves more and more forcibly upon the Russian mind, there must be a call for more Russian railways. Instead of 9,565 miles of line, Russia would probably not be overdone with railways even if 30,000 miles of iron-way were constructed upon her soil. Under all the circumstances, we incline to the opinion that the commercial instinct will become more and more powerful in Russia, and that the Russians will continue for years to come to make more railways, and to consume considerable quantities of our railway iron.

RAILWAY NOTES.

AN OLD LOCOMOTIVE.—A junk merchant here in Worcester is now knocking to pieces an old engine from the Hartford, Providence and Fishkill Railroad, which has stood the vicissitudes of nearly twenty-five years of almost constant service. Mr. Garfield, the master mechanic, informs me that it has run three hundred thousand miles, and that the copper tubes have never required repairs, except the plugging of three of the lower ones. They are 2-in., and are thimbled with cast iron at the fire end. The old machine is in a good state of preservation, the boiler nowise dangerously reduced in thickness.

But the most noteworthy matter about the old engine is the vast accumulation of yellowish scale at the bottom of the boiler. Several of the lower tubes are completely imbedded in this foul matter, and the water space around the fire-box is solidly

packed with it for a foot or so in depth at the bottom, except a small space around the blow-cock; affording unmistakable evidence that there should be a blow-cock at every two feet or less. not only around the fire-box, but beneath the cylinder part of the boiler.—*American Railway Times.*

COST OF RAILROAD TRACK MATERIAL IN NEBRASKA.—Herewith find a few notes relative to the cost of track material per mile in this State, compiled while the first sixty miles of this road was under construction, 1869–'70.

As the figures here given are not materially different from what they would be if revised for the present time, I would suggest that some young engineer employed on Eastern roads furnish you a similar statement, that a comparison may be made, of interest, probably, to many of your readers who have not the time to do it personally.

I will take up the items of rails, ties, spikes, and splices separately and in detail.

The iron for rails came from the Cambria Iron Works, Johnstown, Pennsylvania; had a weight of 57 lbs. per yard, and cost $78 per ton at the works. The freight per car load of 44 bars to Plattsmouth, the initial point of this road, was $187, or about $18.55 per ton additional, or a total of $96.55.

The rail being in 27 ft. bars, excepting a small amount for use on curves ordered 3 in. shorter, a mile of track requires about 391 rails or 89 56-100 tons gross, which at $96.55 per ton gives cost of iron per mile of track as $8,647.

The ties were of hewn oak and came from Central Missouri, principally, and were contracted for so that the price to the company at Plattsmouth was about $1.00 each, of which more than half was paid out by the contractor for freight.

These ties were of a superior quality, 8 ft. long, with 8 in. face. A car load contains from 130 to 150. They were laid 12 to a rail of 27 ft. in length, and, therefore, for a mile there would be 2,347, which, at $1 each, makes $2,347 per mile of track expended for ties.

The spikes used came from the American Iron Works, firm of Jones & Laughlin, Pittsburgh, Pennsylvania; dimensions 9-16 in. by 9-16 in. by 5 in., and cost 4 5-8 cents per pound at the works. These come in kegs of 150 lbs., each containing about 268 spikes. The freight per car load (150 kegs) was about the same as for iron, viz., $187, delivered at Plattsmouth. As the track is double-spiked, it takes 4 spikes to a tie, or 9,388 spikes to a mile, being 35 kegs, or 5,250 lbs. The cost, therefore, per mile for spikes will be: Cost of 35 kegs at works, $242.81, plus freight on same, $43.63, or a total of $286.44. The splices used were also from the Cambria Iron Works, and the price in detail at works, is as follows, per joint:

Fish bars, each 8 2-10 lbs.=16 4-10 lbs, at 3 5-8 c.	59 cents.
4 bolts, each 94-100 lbs.=1 88-100 lbs. at 6 c.	23 "
Total cost at works	82 cents.

The freight charges per car load (1,000 splices complete) being about the same as for spikes, viz., $187, and it taking 391 splices for a mile of track, we have for cost of same, $320.62 at works, plus $73.11 freight, or $393.73. To recapitulate, we have the following:

COST PER MILE OF TRACK FOR MATERIAL.

Rails	$8,647 00
Ties	2,347 00
Spikes	286 44
Splices	393 73
	$11,674 17

To the above must be added the expense of hauling, unloading, laying, surfacing, etc., to give total expended for perfect track, as well as the cost of frogs, switches, etc.—*Railroad Gazette.*

A NEW DOUBLE BOGIE LOCOMOTIVE.—A party of engineers have visited Bristol for the purpose of inspecting a new double bogie locomotive, constructed after the design of Mr. Fairlie. The engine "Hercules" is for the Iquique Railway in Peru. It has four 15 in. cylinders, of 22 in. stroke, and its total weight (60 tons) rests upon 12 wheels, arranged in 2 groups of 6, coupled together, and all assisting in the adhesion. It will be required to work heavy traffic over a gradient of 1 in 25 for 11 miles, and round curves of 3 chains; and during the experiments it went round curves of 2½ chains with the greatest facility, the deflection of the centre of the leading bogie platform from the end of the boiler amounting to 14 in. It was next taken through a boiler shop and a smith's shop, and so upon a very irregular and badly kept piece of line belonging to the Midland Company. Here its trip was interrupted by certain bridges and platforms which it could not pass; but it ran up and down, over a length of about a quarter of a mile, with perfect smoothness. Its passage over roughly laid points was distinctly heard by those riding upon it, but communicated no jolt to the driver's platform. It has been built by the Avonside Company, for Messrs. Montero, of Peru.

THE Hudson River and New York Central Railroad Companies have both adopted a new style of car to be used in the transportation of petroleum. Oil will hereafter be transported over the roads in fire-proof tanks, made of quarter-inch boiler-iron, fastened upon platform-cars. They are filled from a dome at the top, the main hole in which is to be securely fastened when the tank is filled. In case of an accident, it will hardly be possible for the oil to escape; for even in case of severe concussion, no considerable quantity of oil would be likely to escape.—*Am. Railway Times.*

IT is stated by an exchange paper that the Michigan Central and the Great Western road of Canada are virtually consolidated, an agreement for twenty years having been concluded, under which the entire earnings for through business are put into a joint purse and then divided. These are the roads that are to be connected by a tunnel under the river at Detroit.

THE property, rights and franchises of the North Missouri Railroad Company, are advertised to be sold on the 26th of August next, for the payment of $4,000,000, the sale to be subject to a prior mortgage claim of $6,000,000.

THE associated railways of Germany consist of 78 companies, owning 19,145 miles of road; 12 months previously the same companies owned 17,178 miles, showing an increase of 1,967 miles.

FIFTY-SIX miles of the European and North American railway have been completed, which carries the track to "Winn," a distance of 56 miles from Bangor, Maine. The road is to be extended to Vanceborough, which is on the Canadian line. At this point a connection will be made with roads extending to St. Johns and Halifax, N. S., which will form a complete line from Halifax to Boston.

A NUMBER of heavy capitalists propose to span the Andes with a railroad, to connect the Argentine Republic witn Chili. The cost is estimated at $30,000,000.

BRIGHAM YOUNG and his people are waking up to the importance of railroad construction in their territory, and surveyors have been put to work on the route for the Utah Southern road. Mormonism will yield to the inevitable destiny of railway progress.

ENGINEERING STRUCTURES.

PERFORMANCE OF STEAM BOILERS.—Several steam boilers having been entered in competition at the Fair of the American Institute, just closed, the Board of Managers, with their usual liberality, consented to the adoption by the Committee of Judges on Steam Engines and Boilers, of a method of testing which should determine with certainty the relative economic value and steaming capacity of the competing boilers.

Accordingly, the Committee—Professor R. H Thurston, Chairman (of the "Stevens Institute of Technology"), T. J. Sloan and Robert Weir, members, have made such a test of the boilers on exhibition, as, perhaps, was never before attempted.

Under their direction, and under the immediate supervision of the Chairman of the Committee, a large tank was prepared in which about 1,100 ft. of 4 in. pipe was laid, and so arranged that the condensing water from the Croton pipes should flow through the tank, while steam from the boiler at 75 lbs. pressure was blown off into the pipes of this very effective surface condenser.

The pressure of steam, which varied between 70 and 75 lbs., was recorded by an Edson and a Davis recording gauge; the quantity of feed water and of injection, or tank supply, was measured by Tice and Worthington metres; the water of condensation was carefully weighed, and the temperatures of feed and injection, steam, discharge water of tank and water of condensation, and that of the gases in the flues, were all recorded every ½ hour during 12 hours trial of each boiler.

At starting, each exhibitor was allowed to fire up with wood until a pressure of 75 lbs. was reached, when steam was let into the condenser, and the trial was, at that instant, considered as commenced, and firing began with coal. The weight of wood and time of making steam were entered on the log.

At closing, each exhibitor was allowed to burn his fires completely out, if he desired, provided that, at the close of the 12 hours, he had 75 lbs. steam, and the water in his boiler at a point marked at the beginning of the trial by a thread tied about the gauge glass. All that then remained on the grate was weighed back as ash. The meters were allowed to run until all heat was removed from the condenser, although steam was shut off from the condenser at the moment the 12 hours was expired by the Judges' time.

In calculating the results by this method, it is easy to determine, not only the evaporation per lb. of combustible, but also, with great exactness, the condition of the steam, whether wet, saturated, or superheated; in the first case, the quantity of heat transferred to the condensing water will be less, and in the last case greater, than is due to the weighed amount of water of condensation, evaporated at the temperature and pressure in the experiment, as given by our tables for saturated steam.

The log was kept and observations made with great care,—in the presence of all parties interested who chose to attend the trial,—by Students Henderson, Hewitt, Poinier and Post of the classes of '73 and '74 of the "Stevens Institute of Technology" and under the supervision of the Chairman of the Committee, and every precaution was taken to insure correctness.

The results are said to be most creditable to the competitors, and exhibit in a surprising manner the accuracy of this method. They will be published after the Committee shall have completed the Reports in Department V., Group I.

GIANT CHIMNEY AT DOVERCOURT.—There are few localities within an equal distance of London, 70 miles, which possess more intrinsic claims, as a summer retreat, than Dovercourt. It may be said to be a suburb of the thriving and bustling town of Harwich, and is destined eventually, and perhaps at no distant date, to become much better known, and more extensively patronized by visitors. The diversified land scenery within range of vision from its cliffs, and the intermingling of the waters of the Orwell with the German Ocean at the base of the promontory upon which it stands, constitute some of the attractions of Dovercourt.

One of the impediments to a perfect enjoyment of the delights of the neighborhood is at this moment in rapid process of removal. The pure air which naturally exists there has hitherto suffered some contamination from an intermixture with it of the fumes and smoke from a series of cement kilns, ranged in a line in close proximity to the neat little railway-station of the town. In order to obviate this sometimes too palpable annoyance, the owner of the kilns, which are fed with material dredged from the estuary of the Orwell, and from the west rocks near Walton-on-the-Naze, is causing a gigantic shaft to be erected. This is a remarkably well proportioned square built structure, formed of the hardest red bricks and the finest cement of the district. Its height, when finished, will be upwards of 190 ft., and it will form one of the most conspicuous, and in its way, handsome objects of the place. At its base, the giant chimney is 20 ft. sq., and, at its summit, capped with stone, it will be 8 ft. 6 in. across. Some idea may be gained of the large number of bricks used in the construction of the chimney, when it is stated that in a single course at its base 1,500 are comprised. A brick tunnel 100 ft. in length, and of large area, will connect the great landmark, for such it will be, with the apices of the various kilns. The fumes generated by the calcination of the cement stones will thus be carried to a height whence they will be distributed over a much wider area, and of course by

diffusion deprived of the power of irritating the lungs of visitors, and the tempers of the inhabitants of Dovercourt.—*Mechanics' Magazine.*

ORDNANCE AND NAVAL NOTES.

THE GERMAN NAVAL ARMAMENTS.—The defensive works at the mouth of the Weser are to be strengthened by the erection of two new forts, one of which will be built on the Langlutjensand, about 6,000 ft. further down the stream than the works now in course of construction there, while the other will be situated in the vicinity of Bremen. When these are completed, the defences of the Weser will consist of four powerful works from which a double cross-fire might be opened on a hostile fleet. A steamboat has been sent from Kiel for the purpose of running between Geestemunde and Fort Langlutjensand, and as soon as the fortifications are complete the bridge which now unites the fort with the mainland will be broken down, and the former surrounded by water. The newly built screw advice-ships Nautilus and Albatross will next year join the German East Asiatic squadron, which will then consist of 4 vessels, with 48 guns. The Nautilus and the Albatross have been specially constructed and fitted up for this branch of the service, but the experience of late years has led to the conviction that it will be well to modify the plan of constructing a fleet exclusively of corvettes for this station, as in spite of the advantages arising from their superior speed, the comparative weakness of their artillery makes them much less formidable than the heavy, or even the middle-sized frigates of the English or the French navy. The question is therefore now under consideration, whether it may not be advisable to send one or two frigates of a middle size to the East Asiatic waters, which might then be accompanied by a number of swift advice-boats of light draft, but armed with heavy artillery, for the purpose of pursuing and destroying the pirate vessels which infest those seas. In the original plan, the place of the proposed frigates was to be taken by iron-clad corvettes, and the Hansa, now in course of construction, was intended for this purpose. The unwieldy character of the iron-clads, however, renders them but ill-suited for seas exposed to sudden and violent storms, bounded by dangerous coasts, and full of hidden rocks, where, too, in case their machines were injured or any other accident occurred, they could not be properly repaired. On the other hand, it does not seem advisable to diminish the small number of iron-clads which Germany has at her disposal, by sending one to so distant a station.—*Nautical Gazette.*

THE 35-TON GUN.—This splendidly constructed, but at present utterly useless weapon hangs heavily on the hands of the Admiralty. "What will they do with it?" is the question constantly asked, but never as yet answered. To make a good gun of it would be to proportion the length to the bore by adding about 2½ calibres to its length. But it has been built to Admiralty orders, and to the restricted dimensions necessary for a turret. No blame, of course, attaches to Colonel Campbell's department, but we should like to have seen the gun turned out some 28 in. longer, and then have been handed over to the Admiralty to cut down to their dimensions. But of course the gun factory had to work to specifications and drawings, and they are not responsible if the fault of the gun lies in its shortness, which we believe it does. A short time since, there was a talk of lengthening the piece, but then it would be useless for the very purpose for which it was built. So now it is to be re-bored from the present calibre of 11.6 in. to one of 12 in., with rifling of the same twist as at present. This, of course, will reduce the length of the powder charge, and if the Admiralty will only ignite the cartridge centrally, they may probably succeed in burning all the powder, and rendering the gun useful. We sincerely trust they will, but if they do not we confess our inability to suggest any other alternative than the lengthening of the piece, and applying it to another purpose than that of arming a turret ship. It is, however, a patchy way of settling the question after all, and the worst of it is that there are a number of these same guns in a like predicament.—*Engineering.*

NEW BOOKS.

NARROW GAUGE RAILWAYS. By C. E. SPOONER, C. E., F. G. S. London: E. & F. N. Spon. For sale by D. Van Nostrand.

This book, with its numerous maps and illustrations, presents the most complete information on the working narrow gauges.

A TREATISE ON THE RESISTANCE OF MATERIALS. By DE VOLSON WOOD. New York: John Wiley & Son. For sale by Van Nostrand.

This excellent work is a condensation of the ahthor's lectures before the engineering classes of Michigan University. Separate essays on kindred topics have appeared in pamphlet form at different times during the past few years, by means of which Prof. Wood has become favorably introduced to the engineering profession.

The present work, besides presenting in concise form the theoretical bearing of the subject, gives in full reports of the more recent reliable experiments upon materials of all kinds employed by engineers.

The separate topics are Tension; Compression; Flexure and Rupture from Transverse Strains; Shearing: Flexure; Transverse Strength; Beams of Uniform Resistance; Torsion; Long Continued Strains and Shocks; Limits of Safe Loading.

An appendix on Preservation of Timber closes the volume.

The text is illustrated by 122 wood-cuts. Both typography and engravings are well executed.

The work will prove exceedingly valuable, not only to working engineers, but to the *confreres* of Prof. Wood in the scientific schools.

PLATTNER'S MANUAL OF QUALITATIVE AND QUANTITATIVE ANALYSIS WITH THE BLOW-PIPE. By PROF. T. H. RICHTER. Translated by H. B. Cornwall, A. M., assisted by J. H. Caswell, A. M. New York: D. Van Nostrand.

This is the most complete manual of Blow-pipe Analysis ever published. Nothing of importance in the German edition has been omitted, while

several new tests, both qualitative and quantitative, have been added by the translators.

The rapidity and ease with which blow-pipe analyses are applied, has rendered the method popular with the assayers and prospectors of our mining regions. The demand therefore for instruction in this branch of applied science has steadily increased of late. The present work, containing 550 pages, is a complete encyclopedia of blow-pipe manipulation. We shall soon present a complete review of the work.

A Review of the Theory of Narrow Gauges as applied to Main Trunk Lines of Railway. By Silas Seymour. New York: D. Van Nostrand.

This review was called forth by the President of the Texas Pacific Railroad Company, who appealed to the author as a professional authority. The discussion is able and, though brief, exhaustive.

An appendix by S. S. Post, C. E., upon the comparative resistances of the curves of different gauges, enhances the value of the book.

Le Soleil. Par le P. A. Secchi, S. J. Paris: Gauthier Villars. For sale by Van Nostrand.

This treatise by the celebrated Roman astronomer will be gladly received by all who are interested in solar physics. 130 wood-cuts and 3 folding plates illustrate the work.

All the recent observations are brought to bear upon the discussion of the subject, which is thereby rendered the most complete that has been offered to the scientific world.

Logarithmic and Trigonometric Functions. By James Miles Peirce. Gwin Bros., publishers. For sale by Van Nostrand.

This is a collection of 3 and 4 place tables of logarithms and trigonometric functions, containing proportional parts of all numbers up to 100; 3 place tables of logarithms of numbers and of the 6 trigonometric functions, natural and logarithmic, all in one page; a useful table for obtaining rough results and first approximations; logarithms of numbers to 4 places; logarithms of sums and differences (Gaussian Logarithms) to 4 places; logarithmic trigonometric functions to 4 places; inverse trigonometric functions adapted to use with 4 place logarithms; a new table, for finding angles from the logarithms of their trigonometric functions; traverse table; the Correction of the Middle Latitude, in an improved form; Meridional Parts; and Constants, with their logarithms.

The publishers give assurance that the greatest pains have been taken to insure perfect accuracy. It is certain that they have furnished a set of tables, that economize the labor of working for tabular numbers, and save the eye all unnecessary perplexity and fatigue. The editor says:

"Experiments conducted several years ago at the office of the "American Ephemeris" resulted in the conclusion that the times occupied, in regular computation, in doing one piece of work by tables of 4, 5, 6, and 7 places, are proportional to the numbers 1, 2, 3, and 4. It will be seen, then, that 4-place tables have a great advantage over those even of 5 places, wherever the degree of accuracy of which they are susceptible is sufficient for the work to be done, or as great as the probable errors of the data will admit; as, for example, in all the ordinary computations of common surveying, engineering, and navigation, as well as those with which college students are generally occupied.

MISCELLANEOUS.

On the Influence of the Suez Canal on the Commerce in Coals of South Africa.—The "Natal Mercury" says that the construction of the Suez Canal will be an advantage to Natal, especially for the commerce in coals. It is quite true that the opening of the canal has entirely annulled the demand for coals along the coast near the Cape, and that steamers bound to and from India will no longer require to coal at any port in South Africa; but it is also true that steamers to and from Suez will have to coal at Aden, where the demand will soon be increased tenfold. If Natal can supply good coals, no doubt it will find a large demand at Aden. Indian coals are not suitable for steamers, and the coal from England cannot be brought to Aden economically; the supply must, therefore, necessarily come from the mines of the East, and consequently the coals of Natal will find a much better market than if the canal had not been constructed, especially if prepared in agglomerated blocks.—*Mechanics' Magazine.*

Mackie's Steam Justifier and Perforator.—As an important adjunct to his steam type-composer, Mr. Mackie has exhibited during the past month, at the International Exhibition, what he calls his "steam justifier and perforator." The machine is very small and simple. Over the top of a row of punches is made to pass a series of "logos," made of zinc, each representing a letter, word, or sentence. In their passage they actuate the proper punches, so as to secure the exact number of letters and spaces in any line required. It works at the rate of 450 letters a minute, and will be three or four times that speed for Mr. Mackie's 40,000 an hour composer. The ordinary workman will soon learn to pick up these "logos," which are about the size of advertisement rules, and in cases laid much in the ordinary way. Speed, however, can only be secured by the workman using combinations, which he may increase to any extent. Each "logo" represents 3½ letters on the average. It is astonishing how accurately Mr. Mackie's plan secures "justification." So many "logos" weigh exactly the length of type required, and can be varied to a thin space.—*Mechanics' Magazine.*

Slag Cement.—The composition of the slags of the blast furnace should be for the most part as follows, to obtain from them a good cement. Essential elements: silicic acid, 40.28; clayey earths, 15.13; calcareous earths, 36.24. Non-essential elements: manganese, oxide of iron, alkalies, etc., 8.35 One part of these slags in fine powder is sprinkled, and agitated in a suitable vessel, with two parts of an equal mixture of hydrochloric acid (35 per cent HCl) and water. The slags decompose, a lively disengagement of HS taking place. The mass finally forms a thick jelly, from which water removes the chlorides completely. After removing these, the residue is dried and reduced to an impalpable powder; one

part of this powder, intimately mixed with nine parts of slags in powder, gives an excellent cement in water or air, as it may be desirable to apply it. —*Am. Railway Times.*

THE WASHING OF CANAL BANKS.—Much attention has lately been attracted to a plan of protecting canal banks against washing, proposed by Mr. Lawrence Myers, of Philadelphia, and which is one of the inventions brought out by the offer of a State bounty for a successful method of steam canal navigation. Mr. Myers proposes to clothe the sides of the banks of canals with iron plates, ¼ in. in thickness, securely fastened, and suspended about equally above and below the water line. The object of this is to prevent injury to the banks from the wash of passing boats, and the device would be a very good one if there were any serious wash to obviate. As it is, however, the invention is designed to meet an imaginary necessity, so far as the Erie Canal is concerned. It may be that, on some canals, the banks are injured by the wash of which we hear so much, although we have never seen an instance in which such was the case; but the Erie and other New York State canals suffer no such damage, nor is it either necessary or desirable to take the banks into consideration in seeking a solution of the question of steam navigation. This is a mistake which inventors persist in making, notwithstanding the assurance of the Canal Commissioners and the Commissioners of the State bounty, that no possible injury can be done to the banks by any system of propulsion which is mechanically adapted to the business of the canals. If this could be impressed upon the minds of those who are designing and building steam canal boats, many of the imaginary difficulties would disappear, and inventors would be saved the trouble and expense of making costly and useless experiments. If sufficient power is provided for economical traction, the banks will take care of themselves.

SOUNDING THE BALTIC.—The "German Correspondent" says the steam advice ship Pomerani returned from her cruise in the Baltic on the 24th of August. After running from Stockholm to Gothland she anchored on the 20th July in the harbor of Wisby, a little town which lies among the ruins of ancient churches and the towers of fortifications of an earlier age. The Pomerania sailed eastwards till she approached the Russian coasts, and afterwards returned to Gothland, and thence to Memel. She crossed the deepest part of the Baltic in three different directions, steamed along the Prussian coast to Daustic, and then examined the Baltic between the coasts of Pomerania, Gothland, Oeland, and Rügen. After coaling at Stralsand she rounded the Cape of Arkona in Rügen, and passed to the west along the coast of Pomerania, Mecklenburg, and Holstein. During the whole of these journeys soundings were carefully taken, the bottom dredged, the surface and deep-water currents observed, and the temperature of the water at the surface and at some depth, as well as the proportion of salt it contained, determined. The results of these observations will be published after they have been subjected to proper scientific examinations. The greatest depth of the Baltic between Gothland and Windau was found to be 720 ft., not 1100 ft., as was formerly supposed. At the depth of from 600 ft. to 720 ft. the water was, at the end of July, very cold, the thermometer giving from ½ to 2 deg. R. No plants were found at this depth, and only a few specimens of 1 or 2 species of worms were brought up with the clay and mud. The cold probably prevents fresh-water animals from living at such a depth, while the small quantity of salt which the water contains renders it unfit to support sea animals. Animal life abounds from the surface to about 300 ft, below it, while plants were seldom found at a depth of more than 60 ft. The Baltic is supplied with salt water by the Kattegat, through which a deep-water current flows into the Baltic, while the brackish water, which is lighter, streams into the North Sea by a surface current. Both animal and vegetable life, was found to be most abundant on the coasts of Mecklenburg, Schleswig, and Holstein, and in the Bay of Lubeck.

NOVEL MODE OF UTILIZING SEWAGE AT GLASGOW.—Although Glasgow is far behind London in regard to its sewage arrangements, yet it is about to adopt a plan for utilizing part of its sewage, which now runs into and pollutes the Clyde, that London might very well follow, if the several municipal Boards were only to take joint action in the matter. A contract has just been entered into between the Sanitary Committee of the Police Board of Glasgow and a company in that city for utilizing the urinals. The Police Board are to collect and supply to the company 5,000 gallons per day for 12 years, for which the company are to pay the Police Board £1,000 per annum. It will be collected in close tanks, and will be removed during the night to the company's works, where it will be resolved by a chemical process into sulphate of ammonia. The contract is to take effect from the beginning of next year.

ENGINEERING SCHOOLS IN ITALY.—The number of engineering schools (or as they are termed, schools of application for engineers) in Italy are three. During the scholastic year 1868-69 the numner of diplomas granted was 656, being 395 at Milan, 79 at Naples, and 182 at Turin. At the University of Padua there is also a course of engineering, but only two diplomas were granted during the above-mentioned years. The total number of students entered on the books of these schools during the scholastic year 1869-70 was 567, of whom 190 were registered at Turin, 135 at Naples, and 242 at Milan.

THE ROLLING OF GUNBOATS.—The gunboats Bustard and Kite (of the Blazer class), in charge of Captain Charles Fellowes and Staff, of the Steam Reserve, were taken into the offing at Plymouth on Friday, in order to test their rolling motion in a sea way, and discover whether it is easier with the 18 ton in its position on the platform level with the fore-deck, or when it is lowered into the well beneath; and although the weather was not sufficiently rough to subject the vessels to a severe test, yet the result showed that they are much steadier when the gun is up in its position than when it is below. The wind was N. W., force 2, with a moderate sea. The Bustard, with her gun on deck, made only 11 rolls per minute, and the greatest roll was from 7 deg. to port (leeward) to 4 deg. to starboard (windward), but with the gun below she made 14 rolls per minute, the greatest roll being from 9 deg. to port to 13 deg. to starboard, being

3 rolls per minute more with just twice the amount of heel. A similar result was obtained with the Kite.

NEW PROCESS OF CASTING WATER AND GAS PIPES.—The San Francisco "Scientific Press," in a late issue, says: "We were much interested, on Friday last, in examining at the foundry, corner of Harrison and Main streets, a new process which has recently been introduced on this coast, for the casting of water and gas pipes. This process, which is the invention of, and has been patented by John Farrar, of Boston, Mass., consists in the substitution for the ordinary clay moulds, of a sectional three part, cast iron flask, attached together with hinges, and secured by strong wrought-iron clamps. The inside of the flask (which constitutes the mould) is lined up with a preparation of fine clay and plumbago, secured in place by flanges, and which effectually resists the action of heat, over 600 having been cast from one flask without retiring. The flasks were ready for use, and suspended on trunnions, one end projecting over a pit. The process of casting consists of putting in place a core, clamping the flasks and hoisting it up on end; the molten iron is then poured in at the top, filling the space between the core and the flask, and thus forming the pipe. As soon as the metal has 'set,' the flask is brought down to a horizontal position, opened, and the pipe taken out. The lining of the flask is then washed with a preparation of black lead, laid on with large paint brushes, when the process of casting is immediately repeated.

"An average of about 5 pipes an hour is thus made from each flask while the heat lasts, which usually continues from 2 to 3 hours. On the occasion referred to, 3 flasks were alternately used by a gang of 18 men, who turned out a pipe about every 5 minutes.

"The advantages of this process are: The flask makes a permanent mold, admitting of the casting of an indefinte number of pipes without renewal; uniformity in thickness, secured by equal pressure upon the core-barrel, and a close texture of metal and absence of sand holes—porous places which are inevitable where it is cast horizontally. Messrs. Rankin & Brayton, the proprietors of these works, have now 4 flasks in position, from which they are casting from 500 to 600 ft. per day of 4, 5, and 6 in. pipe. Other flasks, embracing all the usual sizes, will soon be in readiness, giving the works a capacity of 1000 ft. per day.

"The usual process for making pipe in the East is that of the ordinary sand mould, which requires an iron flask for each pipe, necessitating a large outlay for the equipment of a foundry of any capacity. The extraordinary advantages of this process are apparent, when it is seen that no moulding is required, and one flask is made to do the work of 12 or 15 on the old plan. This invention is justly regarded by iron men as the most important improvement introduced into this branch of the foundry business. The gentlemen above named have secured the exclusive use of the process for this coast, and the very remarkable facilities it affords will enable them to compete successfully with either Eastern or European manufactures, thus adding another most important and useful industry to our list of local manufactures. Some idea of the saving which this invention will secure to this State may be formed from the fact, that something like 60 miles of pipes are now on the way from the East to this city; but that, in view of the improved facilities hereby offered, no Eastern firm can hereafter afford to enter into competition with the work here. The inventor having made the demonstration here complete will soon go East to introduce the process into the larger Eastern foundries.

"The above firm have been engaged for several months past in filling large pipe orders for the Metropolitan Gas Co., of this city, including some 2 miles of 16 in. drain, now being laid from Montgomery street to the works, corner of Ninth and Brannan. They have also additional orders in hand for some 20 miles of pipes, of various sizes, for the same company, as well as several orders from the interior gas and water companies."

BLASTING TIMBER WITH DYNAMITE.—Last year at the commencement of the war, a tremendous storm inflicted much damage in the great forest of Haye (Meurthe-Moselle). The ground being weak, and the wind exerting a great force against the tops of the trees, a large number were thrown down. Recently the State has taken steps to sell these fallen trees by public auction. The stumps were taken off with the saw, and the trunks were cleared and raised. The beech-roots having become very hard by a long exposure to the air, they could not be cheaply removed and there remained on the ground a very large amount of timber. An engineer thought of applying the method that had been followed with success in similar cases in Germany; recourse was therefore had to dynamite. In each root, and following the axis of the tree, a hole was drilled with an auger from 9 in. to 15 in. deep, and ¾ in. diameter. A dynamite cartridge, of about 50 grammes, provided with a fulminating cap and a length of ordinary mine fuse, was placed at the bottom of the hole. When the charge was tamped the explosion was made, which divided the root into quarters, after which it was easy to reduce it by ordinary means into convenient sizes. By aid of this arrangement each woodman was able to break up 2 cubic yards a day, with an expense of about 3f for dynamite, implements, and hand labor. In this manner profitable results were obtained from timber which would otherwise have been abandoned.

SURFACE MOVEMENTS OF THE EARTH.—M. de Botello describes two contemporary upheavals of the earth's surface, entirely authentic. In the Province of Jamora, it is observed that, from the village of Villar don Diego, it is now possible to see the upper half of the Church-steeple of Renifarzes, a village in the province of Valladovid; whereas, 23 years ago, in 1847, the summit of this steeple could only just be perceived. The same thing occurs to the same degree and under the same circumstances, in the Province of Alava; there it is observed that, from the village of Salvatierra, the whole of the village of Salduende can now be seen, while in 1847 the vane of the steeple could hardly be perceived. The four points mentioned are on the line which would pass by Burgos, and in the direction W. 28 deg. 39 min. S., to E. 28 deg. 39 min. N., that is to say, sensibly parallel to the system of the Sanserrois. A distance of about 140 miles separates the extreme points of the line of upheaval.